BRAYTON STANDARDS

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BRAYTON STANDARDS

A Pocket Companion for

The Uniform Design

of

Reinforced Concrete

by

Louis F. Brayton

Consulting Engineer

Minneapolis

1907

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1970

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PATENT RIGHTS.

Several patents have been issued to me for Reinforced Concrete Construction involving principles utilized in the Uniform Design set forth in this book; and various additional applications for patents have been filed by me relating to such structures. Wishing to render available to the public this design for Reinforced Concrete Construction, I have executed an instrument dedicating and giving to the public all my rights under the said patents and under any additional patents which may be granted on any of the said applications. Hereinbelow is printed a copy of the said instrument of dedication, identifying the said patents and applications.

DEDICATION TO THE PUBLIC.

WHEREAS certain United States and Canadian patents have hitherto been issued to me relating to Reinforced Concrete Construction; and whereas certain applications for United States Letters Patent have hitherto been filed by me relating to such construction; and whereas I am desirous of rendering available to the public all of the said devices:

NOW, THEREFORE TO ALL WHOM IT MAY CONCERN: Be it known, I hereby dedicate and give to the public all my rights under each and all of the hereinbelow identified patents and all rights which may be invested in me under any additional patents which may be granted on the hereinbelow applications, or any thereof.

The said patents and applications above referred to are identified as follows:

United States Patents No. 786,622 issued to me of date April, 4 1905 and No. 791,046 issued to me of date June 6, 1905.

Canadian patents No's. 94,883; 94,884; 94,885 and 94,886, all issued to me of date August 29, 1905. Canadian patents No. 92906 issued to me of date May 22, 1905; No. 92,669 issued to me of date April 18, 1905; and No. 94,875 issued to me of date August 29, 1905.

Applications for United States Letters Patent S. N. 220,745, filed by me August 15, 1904; S. N. 221,592, filed August 22, 1904; S. N. 221,593, filed August 22, 1904; S. N. 222,056 filed August 25, 1904; and S. N. 245,816 filed February 16, 1905.

Signed at Minneapolis, Minnesota, this 25th day of April, 1906.

LOUIS F. BRAYTON

In the presence of
James F. Williamson,
Frank D. Merchant,
Patent Attorneys,
925-933 Guaranty Loan Building,
Minneapolis, Minnesota.

STATE OF MINNESOTA, ss.
COUNTY OF HENNEPIN.

On this 25th day of April, 1906, before me, a Notary Public in and for the County aforesaid, personally appeared Louis F. Brayton, to me known to be the identical person who executed the foregoing instrument, and acknowledged that he executed the same as his own free act and deed.

Stephen Mahoney, Notary Public,
Hennepin County, Minnesota.
My Commission expires February 7, 1913.

SEAL.

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INTRODUCTION.

Reinforced concrete has ceased to be an experiment in the hands of the specialist. The strength of the various members required in the composition of a structure, can be as safely calculated in reinforced concrete as they can be in wood or steel. The principal difficulty at the present time lies in the fact that the specialists doing this class of work are largely in the employ of companies who are exploiting some particular feature in the line of reinforcement.

Architects and engineers have grown into the habit of specifying that the contractor shall furnish the designs for the reinforced portions of the work under consideration. General contractors in turn have been obliged to go to subcontractors who make a specialty of this line of work to get the designs. The result has been that no two competitors base their bids upon the same design. The one accepted may be unnecessarily expensive because of the patented features in the reinforcement used, or it may be unsafe because of the insufficiency in the materials, or an inefficiency in the design.

Brayton Standards is a compilation of information acquired from actual experience, coupled with the necessary theory. The methods of construction shown are not merely theoretical, but have been put into practice and found highly efficient and economical. No patented bars are used, although there could be no objection to them if placed in equivalent quantities, and in the forms shown. Plain, round rods are the cheapest form of reinforcement, as they may be bought in any market and are not subject to the prices quoted upon bars of special design. They will accomplish every duty required of them if they are placed in the proper form, as indicated in the accompanying details.

Where some type of deformed bar is considered necessary to aid the adhesion of the concrete, plain twisted square bars may be used, or there are a number of forms of patented bars on the market which serve their purpose admirably, and can be recommended.

The primary object in placing these tables and details in such form as to be available for the use of all, is to enable architects and engineers who have not made a specialty of this class of work, to show the complete drawings required to properly illustrate a structure in reinforced concrete, so that all contractors bidding upon the work will bid on a uniform basis, and upon a design which is entirely satisfactory to all those concerned.

Brayton Standards are conservative, and as accurate as is consistent with this class of work. It is hoped that the use of them will render the design of reinforced concrete as easy for architects, engineers and builders as is the design of steel structure at the present time.

PREFACE TO SECOND EDITION.

The progress made by reinforced concrete during the past year is something wonderful. Concrete as an element in construction, is increasing in popularity at a rate never equaled by any building material, structural steel probably not excepted.

A few years ago we were living in the steel age; today it is the concrete age and it looks as if concrete would last well over into tomorrow.

This wonderful progress may be attributed to the brains of able engineers probably more than to any other source, for the success of the material is entirely dependent upon the design. Where five years ago a collapse of a concrete building proved a tremendous set-back to the form of construction, today it serves only as a lesson to the penny wise and pound foolish owner, who has consented to anything offered in the way of reinforcement, which would cost the least money.

Every collapse is a boost to the honest designer, for it has been shown in numberless cases that failure is the result of foolish economy.

Brayton Standards was placed on the market a year ago for the benefit of the profession, to serve as a guide to correct design and to help

guard against failures which are no fault of any one but the designer. That it has served its purpose to a certain degree we feel assured for it has received the approval of *practical* men everywhere. As in every new undertaking there have been those who do not agree, but the objections have been trivial and are largely by those having no experience in *practical* construction, the error being charged on the side of safety.

Brayton Standards are designed with a practical knowledge of the contracting side of the business as well as the theoretical, and consequently the elements of workmanship are sometimes given weight in tables which are not apparent from the standpoint of the theorist. Another element which enters into the tables is the question of building laws. Various cities have various requirements but on some points such as strain on concrete in direct compression or on the extreme fibre in bending they are almost universally agreed. It is obvious that tables not in accordance with these laws although possibly theoretically correct, would be of little *practical* value to designers until the laws are revised.

There are some points however brought out by investigators during the past year which it would seem advisable to take into consideration in the second edition of Brayton Standards. Most important among these is the adoption of hooped concrete columns in place of those having binders at intervals of one foot. This is more fully discussed under the subject of columns.

All those interested in the betterment of design of reinforced concrete are invited to make such suggestions as may be of *practical* value, for it is our aim to make Brayton Standards the *standard* of practical construction.

THE UNIFORM DESIGN

OF

REINFORCED CONCRETE.

PRINCIPLES OF DESIGN.

In the planning of a structure in reinforced concrete, as well as in other materials, there are two questions of utmost importance: The question of capacity to perform the duties imposed upon the structure, and the question of cost. The two are so closely related that each must be kept continually in mind when the other is under consideration.

The tables contained herein are prepared in such a way as to be simple in their use, but it is left to the designer to use them to the best advantage from the standpoint of economy.

Particular attention is called to the use of continuous construction in slabs, and especially when it is used in the form of "two-way" reinforcement, supported upon the four sides of the panel. The maximum economy is here attained.

A word of caution, however, may prevent an error in the calculation of oblong panels of the "two-way" type. The method by which these panels are calculated is explained on another page.

Another frequent source of error is the neglect of the *end span*, where continuous reinforcement is used. This span should be calculated by a different formula, as noted in connection with the illustrations.

From the standpoint of economy, the sizes of beams should be maintained the same throughout the building, if at all possible, for the reason that it will be far more economical to buy enough lumber for only about one third the floors, manufacture the beams into permanent forms, and use them three times during the construction of the building, than to rebuild the forms for so many different sizes of beams. With this arrangement, as the lower floors become sufficiently set to become self supporting, the forms may be removed and used in the upper stories. If the beams in the upper stories are of smaller dimensions than they are below, the labor of remodeling forms will cost far more than the extra concrete would if the beams were made of the same dimensions as used under the heavier capacities. Even the roof with its extremely light load may be more economical if the large sized beams are used.

If for any reason it is necessary to change the sizes of the beams, then the dimensions should be arranged in such a way that the forms can be conveniently changed without ripping the lumber. This might be attained by making an even four-inch change in depth, so that if the

forms were built using a 2x4 in the side, it could be removed to give the shallower depth beam.

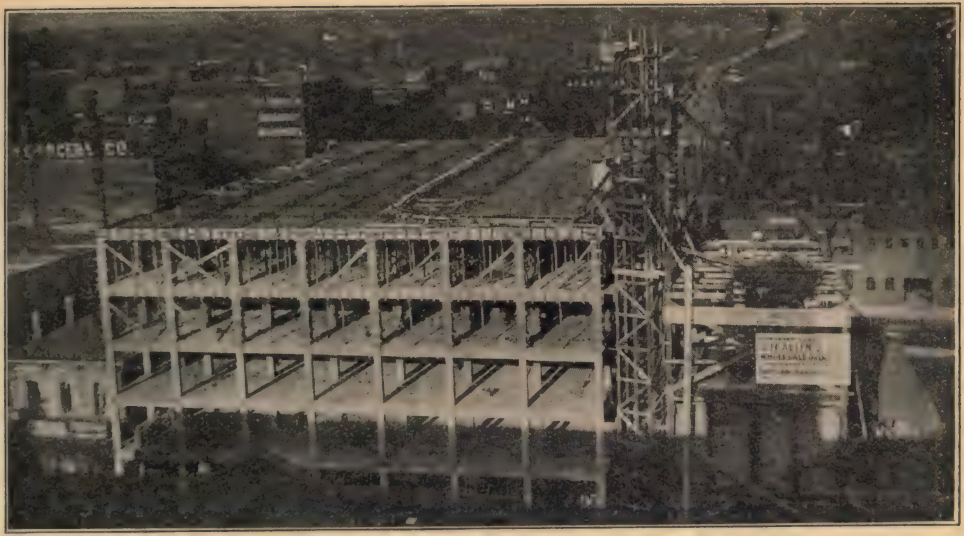
The same principal occurs in the construction of columns. It is economy to use the same sized columns from the basement to roof, or at least, not change the size of columns more than once, throughout the height of the column stack. If the column is changed in size one or two inches at every story, it will mean not only remodeling all column forms, but the splicing out of beam forms in order to make them properly fit the new dimensions.

Skeleton construction in reinforced concrete is another point demanding the careful consideration of the designer. Skeleton construction is understood to be that form common in steel buildings, where the exterior walls are carried at each floor by means of spandrels to columns which thus support the wall.

This form of construction is desirable in reinforced concrete buildings for two good reasons. First; the entire skeleton being of reinforced concrete the contractor's organization, works with a maxium efficiency. There is no loss of time waiting for the construcion of bearing walls. The smaller the building the more important this is. It has been shown by experience that on a small building the contractors force will be completely disorganized twice during the construction of each story if skeleton construction is not used. This means an unnecessary expense. Second; the reinforced concrete skeleton being built several stories in advance of the brickwork, every advantage for rapid drying is afforded. The wind unobstructed blows through the structure carrying away superfluous moisture

and hastening the time of completion of the building. Many an owner has found to his sorrow that his building, built with bearing walls, retained its moisture in about the same way that a bottle does.

Skeleton construction affords more rapid progress, is more economical, drys quicker and gives a better anchorage for the ends of beam rods. It should be used wherever possible.



TYPICAL SKELETON CONSTRUCTION

THE THEORY OF THE BEAM.

Numerous tests have been made on reinforced concrete beams by those making a specialty of the study of the resistance of materials. The universities in particular have greatly added to the knowledge of the subject by very careful observation on specimens under test.

In any beam of any material, when under flexure, there are of course two general strains developed, tension and compression equal and opposed to each other. This is one of the fundamental principles of the beam. It is readily seen however that there is a portion of the beam lying some place between the center of tension and the center of compression which is under very little strain of either character. In fact there must be a point which is under no strain whatever. This point is known as the neutral axis.

In a material such as steel where the coefficient of elasticity is practically the same in compression as in tension, the neutral axis in a beam of uniform cross section lies at the center. In a reinforced concrete beam however where, the entire tensile strains are performed by the steel, and compression is resisted by the concrete, the location of the neutral axis is at some very uncertain point between. If the depth of the concrete beam remains constant the location of the neutral axis may be influenced by the amount of steel used in tension, or by the strain to which the steel is stressed, or if the steel remains constant, the location of the neutral axis may be influenced by variations in the concrete.

The significance of the location of the neutral axis lies not in the point itself, but in fact that it determines the area of the concrete under a compression strain.

This compression area extending from the neutral axis to the extreme fibre, is under various strains in various portions of the area. Certainly in the portion directly adjacent to the neutral axis the strain is zero, and certainly at the extreme fibre, the strain must be at a maximum. The portions between vary with their distance from the neutral axis. If these strains were plotted so as to show the strain with its distance from the neutral axis, very careful experiments would indicate the compression area to be in the form of a parabola with its vertex at the extreme fibre and its axis parallel thereto.

In practice however it has been customary with most designers to assume that the compression strain various directly as its distance from the neutral axis. Thus, if plotted, the compression area becomes a triangle with its center of gravity, or the center of compression, at two thirds of the distance from the neutral axis to the extreme fibre. Adding this distance to the distance from the center of tension to the neutral axis gives the total distance between the centers of tension and compression, which multiplied by the total compression gives the moment of resistance of the section.

Before proceeding with the developement of the formula for the solution of the reinforced concrete beam the readers' attention is called to a few points bearing on the subject.

In the first place the object of this treatise is not to develop general formulas for universal application or to detail the exact theoretical solution of all beams.

The first and last predominant idea is to produce a treatise of *practical* value and one which will give practical answers to the designer under conditions which the market and common practice afford.

Considering the question of concrete, the theoretical man will say the proportions of cement, sand and stone will determine the coefficient of elasticity which in turn will determine the neutral axis and consequently the moment of resistance. This may be true but in practice we know that the laborer has far more to do with the coefficient of elasticity than he is aware of and the city ordinance generally, requires that an extreme fibre stress of not more than 500 pounds per square inch shall be used.

In steel the careful methods of manufacture determine pretty accurately the coefficient of elasticity, but stock sizes and the open market, do not supply the high carbon bars recommended by the theorist. These are controlled by patent rights or delayed in the mills for special rolling when the captains of this great industry see fit to accomodate the customer.

With these points in mind a formula may be produced which will be of good practical value.

It will be assumed that concrete is mixed in the proportions of one part of Portland cement, to two and one-half parts of sand, to four parts of broken stone or gravel and that it is to have an extreme fibre strain of 500 pounds to the square inch. Steel is assumed to be the kind available

in the open market of medium Open Hearth or Bessemer process of manufacture and to have a working tensile strain of 16000 pounds per square inch. Tests have shown that although as much as one and one-half per cent of steel of this grade may be used in concrete, about seven tenths of one per cent is more economical, and consequently these standards, considering economy of vital importance, will assume the use of this amount of steel as correct. Tests have also shown that with the above conditions the neutral axis is located at a point about 0.45 of the distance from the extreme fibre to the center of gravity of the steel.

The economy in the use of 0.7 of one per cent of steel lies in the fact that if less than 0.7 of one per cent is used, stressing the steel to only 16000 pounds per square inch, the compressive resistance of the concrete is not utilized up to an extreme fibre strain of 500 pounds per square inch, and therefore there is a superfluous amount of concrete and unnecessary dead load. If on the other hand more than 0.7 of one per cent is used, it can not be stressed as high as 16000 pounds per square inch, or the extreme fibre strain in the concrete will exceed the allowable 500 pounds, thus the steel is not economically stressed.

This economical percentage, it will be remembered, is based on the assumption that the compression area in a concrete beam is triangular, that is the unit stress varies directly as the distance from the neutral axis.

Some designers assume that the compression area in a concrete beam, is parabolic in form, and numerous tests seem to indicate the justice of the assumption. The parabolic compression area

is not considered by many city ordinances however and until it is more generally recognized as being correct it will not be used in these standards.

The essential difference between the two assumptions lies in the fact that in the parabola, the area being larger than in the triangle, the total resistance to compression at a unit pressure of 500 pounds on the extreme fibre is greater, hence a larger percentage of steel may be used. When steel is designed at a stress of 16000 pounds per square inch, it is most economical to use 0.87 of one per cent, assuming the parabolic compression area, the economy being based on the reasoning already given.

Thus the assumption of parabolic compression justifies the use of about 25 per cent more steel at the same stress, than can be economically used under the theory adopted in these standards. However until practice and additional tests fully demonstrate the correctness of the parabolic assumption, it would seem wise to adhere to the more conservative formulae given and tabulated here.

Now assuming a beam of one foot or twelve inches in width and a depth of one inch from the center of tension to the extreme fibre, the formula under the above conditions, is easily evolved from the diagram given herewith.

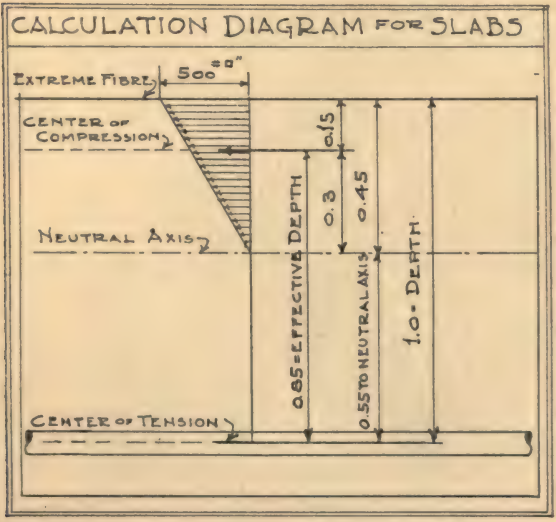
It is assumed the compression area is a triangle with its center of gravity at two-thirds of the height. The neutral axis is located at a depth of 0.45 of the distance from the extreme compression fibre to the center of tension. Thus the effective depth which is the distance between the centers of tension and compression, is equal to 0.85 of the distance of the center of tension

from the extreme compression fibre.

The total compression area in the concrete is equal to $12 \times 0.45 = 5.4$ square inches, which at an average pressure of 250 pounds per square inch, gives 1350 pounds as the total compression in the beam assumed.

Since the tension in a beam is always equal to the compression, the total tension in the beam assumed is also equal to 1350 pounds.

Since the moment of resistance of a beam is equal to the product of the total tension, multiplied by the distance between the centers of tension and compression, the moment of resistance of the beam assumed, in foot pounds, is equal to 0.85 divided by 12 and multiplied by 1350, which is equal to 95.62 foot pounds.



This diagram is designed with the idea that the extreme fibre will attain its full safe capacity of 500 pounds per square inch, which is a factor of safety of at least four on the concrete when the steel is stressed to one-half its elastic limit giving the regulation factor of safety of two required for steel in combination with concrete.

For the properties of *any* beam developing the full capacity of the concrete, the process of calculation is merely by comparison with the beam 1 inch deep as already explained. Thus, where *the depth* means the distance from the extreme compression fibre to the center of tension in inches, the total capacity in pounds of the compression flange of a rectangular beam is 1350 times the depth. The tension being always equal to the compression in a beam, *the tension* in pounds *in any beam is equal to* 1350 *times the depth in inches.* Steel supplying tension in addition to this amount is not economically used.

Since the tension in a beam and the effective depth, or the moment arm, are each directly proportional to *the depth,* the moment of resistance, which is the product of the two, is proportional to the *square* of the depth. Hence, by comparison with the beam one inch in depth, *the moment of resistance of any beam in foot pounds is equal to* 95.62 *times the square of the depth in inches.*

Example: (1). What is the moment of resistance of a reinforced concrete beam 12 inches wide by 20 inches deep. (2). What is the area of steel required, the steel having an elastic limit of 32,000 pounds per square inch.

Answer:

(1). Moment of resistance $= 95.62 \times 20^2 = 38248$ foot pounds

(2). Area of Steel $= \frac{1350 \times 20}{16000} = 1.69$ square inches.

THE LOCATION OF THE STEEL.

A reinforced concrete beam or floor slab is nothing less than a truss, and it may be treated in exactly the same manner. A truss may have its tension web members on the vertical or diagonal. It is equally good either way but the efficiency of these members is absolutely limited by the strength of their connections at either the bottom or the top chord.

The same thing is true of the reinforced concrete truss. It should be laid out with an effective depth of 0.85 of the total depth, and calculated in the same manner as a truss of any ordinary type. The concrete will fulfill the requirements of compression in the top chord and web, and steel should be placed to take the tension in the lower chord and web. Steel web members, as in the ordinary truss, should be proportioned to the stresses in them and they should be provided with a method of connection to each chord of sufficient strength to develop these stresses.

A beam or girder is usually used in connection with the floor slab, and the two are so thoroughly bonded together that they act as one in the form of a tee-section. The slab, like the compression flange of an I-beam, assists in providing the compression strains in the beam. There is a source for argument as to how far out into the slab it may be considered that the tee-section extends, the slab acting with and as a part of the compression area of the beam; but it is perfectly logical to assume that this slab does take some of the compression of the beam, the same as the flange plates in a plate girder are made to

resist the compression stresses by means of their connection through the flange angles and rivets to the web.

In ordinary construction, where the floor slab runs as thick as 5 or 6 inches and the tension stresses of the beam are not exceptionally large, there is not much question but that the slab will supply all of the compression required without assuming its width to be more than three or four feet.

In thin slabs, however, or where the beam is of such a high capacity as to require a great amount of steel in the tension flange, the slab may be called upon to supply an excessive amount of compression. In this case the test of how wide a portion of the slab may be considered as acting in compression with the beam, should be the shearing value of the slab both vertically and horizontally where it connects with the beam. The principal is the same as the calculation of rivet spacing in the flange of a plate girder. If the arrangement of steel is provided as shown in these standards, the shear along the plane of the lower side of the slab is amply provided for within the steel members as they pass from the lower flange of the beam, up into the slab and over the point of support.

In cases where the slab is so thin as not to be considered of value in providing compression, steel reinforcement in the form of rods imbedded in the compression chord of the beam should be provided in sufficient quantity to give it the required strength and reduce the fibre strain in the concrete to a maximum of 500 pounds to the square inch. In placing these rods in the compression chord of the beam, care should be taken

that they are so located as to be thoroughly bonded to the rest of the beam by means of their intermingling with the shear loops.

The correct location of the steel, in concrete structures, is primarily determined by the designer, but too much emphasis cannot be placed upon the fact that the question of proper erection is as vital to the success of the construction as proper design. A good design may prove an utter failure if not properly executed.

A common failure in workmen of every class is to try to hide mistakes, and to the average man a mistake never discovered is as good as a mistake repaired and much more pleasant to him.

Concrete offers many opportunities to cover up or hide from view reinforcement improperly placed or even entirely lacking. One case a couple years ago, came to light in which the foreman was placing great quantities of steel in a body of concrete where none was required because he had it on hand and thought he had made some error in omitting it from other portions of the work. In another case where the designer had shown bars in the four corners of a column, the bars after the collapse were found to be huddled together near the center of the column.

Attention is called to these methods here to warn the engineer that his work is only half done when the plans are completed. He should survey all reinforcement after it is completed and before the concrete is placed.

If continuous reinforcement is used in slabs care must be taken that the reinforcement is close to the top of the slab over the point of support. Remember that an inch or two out of place may decrease the calculated strength by

twenty-five or fifty per cent. The washers on the slab rods should be inspected to see that they give the proper amount of concrete under the rods for their protection and stapling of the rods to the forms must be ample to secure the latter in their proper position and prevent displacement when the concrete is placed.

Beam reinforcement must be inspected to see that loops are properly spaced and rods are properly separated and given the correct amount of fireproofing, and that the beam has the proper bearing on the wall.

Note the column reinforcement. The vertical rods should be properly milled, should be set vertical and properly secured to the hooping. The hooping should be evenly spaced and secured to withstand the pouring of the concrete.

In short it should be seen that all reinforcement is placed as it is designed, for the best design may prove the worst failure, by careless erection of the reinforcement.

DISTRIBUTION OF LOAD IN A RECTANGULAR PANEL.

From the standpoint of economy it is advisable always to reinforce a concrete slab in two directions. By this arrangement of the steel, whether it is simple or continuous, the load is carried in two directions and is supported on the four sides of the panel by means of the surrounding beams or walls.

In calculating a square panel it is natural to assume that half of the total dead and live load per square foot is carried in each direction and this assumption is correct. In the calculation of a panel of greater length than breadth, however, it will be readily seen that economically, a larger portion of the load may be carried on the short span than on the long span. This is because if too large a proportion of the load is considered as carried on the long span, it will require so thick a slab to supply the required moment of resistance that the dead load will be materially increased, and the remainder of the load carried by the short span will not require a moment of resistance anywhere near as large as that supplied by the slab, which may be considered as so much wasted strength.

The ideal division of the load for economy is in proportion to the squares of the two spans. Since bending moment varies in proportion to the square of the span also, it will be readily seen that if the load is considered as being so divided, the bending moment produced by the smaller load carried by the longer span, will exactly equal the bending moment produced by the larger load

carried by the shorter span, and the same moment of resistance would be required in the slab in each direction. Thus a slab may be adopted which will be utilized to its fullest capacity in each direction. Since the moment of resistance is the same, the reinforcement will be the same and any size and spacing of rods adopted for one direction will be used similarly on the other span, which the contractor will recognize as a matter of great convenience and economy in construction.

Text books treating this subject theoretically, say that the slab under a load must have some deflection, which causes a much greater distortion in the short span than in the long, and that consequently the total load should be considered as divided in proportion to the strains caused by this deflection. Calculations according to this theory indicate loads carried by the short spans about twenty per cent larger than are given when the loads are divided in proportion to the squares of the spans, and the loads on the long span are of course correspondingly smaller. This theory may be worthy of consideration for the one square foot at the exact middle of the panel, but for any other portion of the panel it will not hold, for the reason, that although the point selected, may be in the center of one span, it will not be in the center of the other, or it may not be in the center of either span, and the laws of deflection would not hold. Furthermore the question of deflection is largely influenced by continuous construction, and any definite laws governing deflection in a panel have never been determined.

The first edition of Brayton Standards gave a table for the division of loads in accordance with the theory of deflection but a careful consideration of the subject has lead to the division in proportion to the squares of the spans and a table is here given accordingly.

It will be seen that in a panel perfectly square, where the length is equal to the breadth, the ratio is one, and that an equal amount of the load is carried in each direction. In this case the designer would assume the dead and live load per square foot, divide this by two, and calculate the thickness of slab, and the amount of reinforcement required to carry this load on the span given. The total reinforcement required for the slab would be equal to double the amount required by this calculation, as it would be used in both directions.

In case the ratio of the length to the breadth should be 1.2, the table shows that 0.59 of the load is carried on the short span and 0.41 of it is carried on the long span. The method of calculation in this case is to consider 0.59 of the total load per square foot as being carried on the short span, and the thickness of slab and reinforcement is determined by these assumptions. Having determined the thickness of slab, and size and spacing of rods for the short span, the same size and spacing of rods should be used for the long span, for 0.41 of the load on the long span will produce the same bending moment and consequently the same moment of resistance will be required.

Particular attention is called to the fact that in all formulae given in connection with the diagrams, W represents that portion of the total

dead and live loads per square foot, which is carried in the direction of the span under consideration.

The designer must also remember in designing beams for oblong panels that the long beam will have to carry the load put on it by the short span of the slab, while the short beam will have a very much lighter square foot load.

DISTRIBUTION OF LOAD IN A RECTANGULAR PANEL

Length Divided by Breadth	1.0	1.1	1.2	1.3	1.4	1.5
Proportion of total load per sq. foot car'd by short span	0.500	0.548	0.590	0.628	0.662	0.692
Proportion of total load per sq. foot car'd by long span	0.500	0.452	0.410	0.372	0.338	0.308

Length Divided by Breadth	1.6	1.7	1.8	1.9	2.0	
Proportion of total load per sq. foot car'd by short span	0.720	0.742	0.764	0.784	0.800	
Proportion of total load per sq. foot car'd by long span	0.280	0.258	0.236	0.216	0.200	

SLAB REINFORCEMENT.

These standards illustrate the different methods of placing reinforcement within slabs as required to fulfill the various conditions. In cases where slabs bear upon walls, it may be impossible to get continous construction, and the simple span, "one way" reinforcement may be the one type available.

The designer should always, if possible, manage to insert beams so as to divide up the slab into rectangular panels as near square as possible, and to place the steel in two directions. This "two-way" reinforcement has an economy in it, whether it be of the simple or continuous type, for, because of the panel effect, it is permissible to calculate the bending moment more economically.

In slabs, reinforcement should be placed so as to provide for the shear. This is especially true where long spans are used. Shear is amply provided for when the rods are placed as shown in the accompanying details.

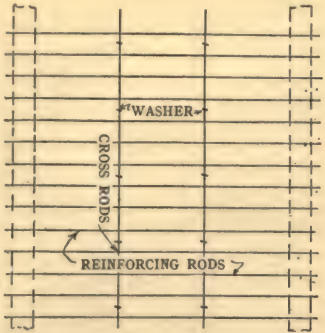
A form of continuous reinforcement is shown which is easily bent and easily erected. Variations of this form are used by some designers, but if any have advantages they also have disadvantages. The form here shown is recommended as being satisfactory in practice.

The continuous reinforcement shown here and designated as *double continuous* derives the name from the fact that each bar is continuous at each end. The effect is to produce a reinforcement which has *double* the strength over the support, that it has at the center of the

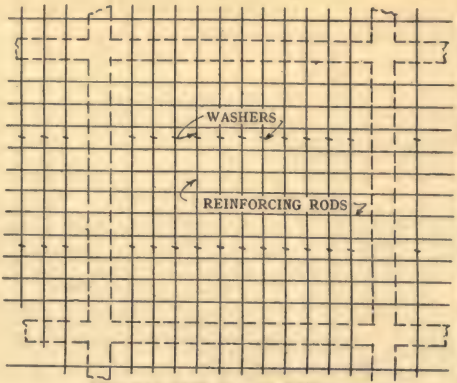
span and this may be taken advantage of in the design. Some designers in using this type of bar consider the same formula, for the bending moment over the support, as is used in the ordinary type of continuous construction, assuming the bending moment at the center of the slab to be only half as great. In these Standards this is considered too liberal an assumption and the formulae are arbitrarily cut down to those given in connection with the cut.

Attention is called to the use of the spacing bar in both simple and continuous forms. It should be used along all beams and walls and if properly erected will serve to hold the slab reinforcement in place.

Slab reinforcement should be held off of the forms by having cut washers strung over as many bars as required to accomplish the purpose. The location of reinforcement should be secured by means of plenty of staples driven into the forms and by tieing to the spacing bars with wire.

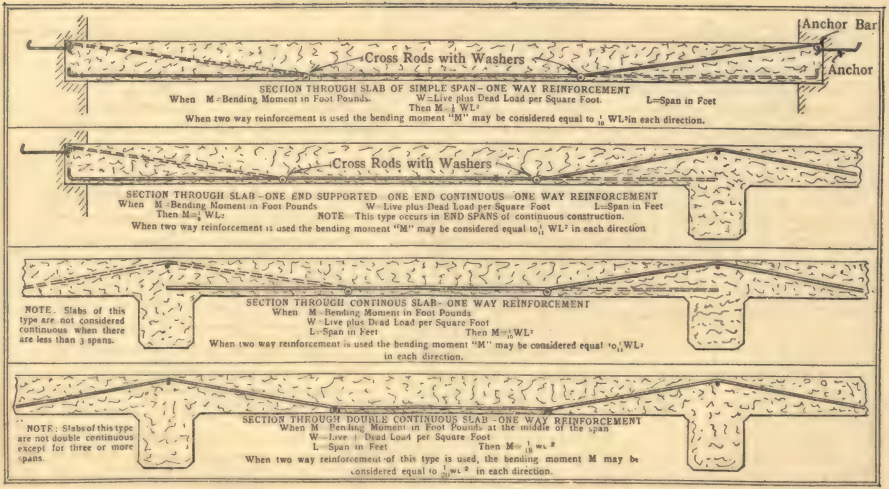


ONE WAY TYPE OF SLAB REINFORCEMENT
Cross Rods are used to act as bridging in the slab and to hold the reinforcing rods up from the forms. The cross rods are held up from the forms by means of washers.



TWO WAY TYPE OF SLAB REINFORCEMENT
This type may be either simple or continuous span or both may be used. Washers are strung over the lower system of rods to hold them up from the forms. Rods are held in place by means of staples.

SLAB REINFORCEMENT.


Anchor Bar
Anchor
Cross Rods with Washers
SECTION THROUGH SLAB OF SIMPLE SPAN - ONE WAY REINFORCEMENT
When M = Bending Moment in Foot Pounds.
W = Live plus Dead Load per Square Foot
L = Span in Feet
Then M = 1/8 WL²
When two way reinforcement is used the bending moment "M" may be considered equal to 1/10 WL² in each direction.
Cross Rods with Washers
SECTION THROUGH SLAB - ONE END SUPPORTED ONE END CONTINUOUS - ONE WAY REINFORCEMENT
When M = Bending Moment in Foot Pounds
W = Live plus Dead Load per Square Foot
L = Span in Feet
Then M = 1/11 WL²
NOTE This type occurs in END SPANS of continuous construction.
When two way reinforcement is used the bending moment "M" may be considered equal to 1/11 WL² in each direction
NOTE. Slabs of this type are not considered continuous when there are less than 3 spans.
SECTION THROUGH CONTINOUS SLAB - ONE WAY REINFORCEMENT
When M = Bending Moment in Foot Pounds
W = Live plus Dead Load per Square Foot
L = Span in Feet
Then M = 1/10 WL²
When two way reinforcement is used the bending moment "M" may be considered equal to 1/11 WL² in each direction.
NOTE. Slabs of this type are not double continuous except for three or more spans.
SECTION THROUGH DOUBLE CONTINUOUS SLAB - ONE WAY REINFORCEMENT
When M = Bending Moment in Foot Pounds at the middle of the span
W = Live + Dead Load per Square Foot
L = Span in Feet
Then M = 1/18 WL²
When two way reinforcement of this type is used, the bending moment M may be considered equal to 1/20 WL² in each direction.

DETAILS OF SLAB REINFORCEMENT.

BENDING MOMENT IN SLABS FOR VARIOUS TYPES OF REINFORCEMENT.

There are here illustrated two general styles of reinforcement, the simple and the continuous. The simple span under some conditions may be combined with the continuous construction, as shown between the other two types. Either the simple span, or the continuous span, or the combination simple and continuous span may be used in two directions in the same panel. Thus, in all, there will be six types of reinforcement, and under every type a different formula is used for the calculation of the bending moment.

In determining the formulae for various types of construction it should be noted that practice rather than theory must govern. It is acknowledged that the bending moment in continuous spans is about 1-12 WL^2, but city ordinances which touch upon the subject, require the use of 1-10 WL^2. City ordinances also require the use of 1-24 WL^2, in square panels of the two way continuous type of reinforcement, W being the total load per square foot. While it is generally acknowledged that this is a very conservative theory, the practice has so far continued because of the uncertainties in workmanship. These standards, therefore, being intended for practical use will conform to common practice.

For the simple span one-way type of reinforcement, M is equal to $\frac{1}{8}$ WL^2 where M equals the bending moment in foot pounds, W equals the dead plus the live loads per square foot and, L equals the span in feet.

When this type of reinforcement is used in two directions the strength of the slab is very materially increased because of its being supported on the four sides, and it will be *more than twice* as strong, as if it were supported on two sides. Under these conditions the bending moment is considered equal to 1-10 WL^2 *in each direction,* W being considered that portion of the total dead and live loads per square foot carried on the span under consideration.

For the combination of the simple and the continuous type one-way reinforcement, M is equal to 1-9 WL^2, and for this same reinforcement of the two-way type M may be considered equal to 1-11 WL^2 in each direction, W and L having the values as stated above.

For the continuous one-way type of reinforcement, M is to be calculated as equal to 1-10 WL^2, and where the two-way type continuous reinforcement is used M may be considered to be equal to 1-12 WL^2 in each direction, W and L being subject to the conditions stated above.

For the double continuous one-way type, M is to be calculated as equal to 1-9 WL^2 over the beam and 1-18 WL^2 at the center of the span, and where the two-way double continuous type is used, M may be considered equal to 1-10 WL^2 over the beam and 1-20 WL^2 at the center of the span, W and L being subject to the conditions stated above.

All tables here given, which involve the question of bending moment, are calculated for the simple span of the one-way type of reinforcement, where the bending moment M, equals $\frac{1}{8}$ WL^2. In order to use these tables with other types of reinforcement the total dead and live load per

square foot should be reduced to an *equivalent* load per square foot, by multiplying the load under consideration by a coefficient corresponding to the type of reinforcement adopted. The results given, by using this equivalent load in the tables, will be correct for the corresponding type of reinforcement.

The coefficients for the various types are as follows:

Coefficient for simple one-way type	1.000
" " combination simple and continuous one-way type	0.888
Coefficient for continuous one-way type	0.800
" " simple two-way type	0.800
Coefficient for combination simple and continuous two-way type	0.727
" " continuous two-way type	0.666
Coefficient for double continuous one-way type at center of span	0.444
Coefficient for double continuous two-way type at center of span	0.400

BENDING MOMENT IN SLABS FOR VARIOUS LOADS AND SPANS.

For slabs of various spans under total uniform live and dead loads per square foot, ranging from five-foot to twenty-four-foot spans, and from 75 pounds to 1000 pounds load per square foot, the bending moment in foot pounds is given on the following pages.

These tables are for the use of those who prefer to use tables instead of a formula to get the bending moment for various loads and spans. After knowing the bending moment the thickness of slab and size and spacing of rods required, may be found by the moment of resistance tables or from the table giving the properties of slabs.

Example: What is the bending moment in foot pounds for a simple span of 12 feet of the one-way type of reinforcement under a load of 250 pounds per square foot?

Answer, 4500 foot pounds.

Example: If the span is simple, uniformly loaded, of the two-way type of reinforcement, the panel being square, what bending moment, in each direction, will be attained for a panel 14′x14′, under a total load of 500 pounds per square foot? (see preceeding page.)

Answer: 0.5x0.8x500=200 pounds per square foot, the amount to be used in the table. The bending moment would be 4900 foot pounds per foot of width in each direction in the slab.

The bending moment in continuous slabs may be similarly obtained.

BENDING MOMENT IN SLABS

In Foot-Pounds per Foot Width

Simple Span–One Way Type.

Span of Slab in Feet	LOAD PER SQUARE FOOT Live plus Dead					
	75	100	125	150	175	200
5′	235	310	390	470	550	625
6′	340	450	560	675	785	900
7′	460	615	770	920	1075	1130
8′	600	800	1000	1200	1400	1600
9′	760	1010	1260	1520	1770	2020
10′	940	1250	1565	1875	2190	2500
11′	1130	1510	1880	2260	2640	3000
12′	1350	1800	2250	2700	3150	3600
13′	1600	2100	2650	3150	3700	4250
14′	1850	2450	3100	3650	4300	4900
15′	2100	2800	3500	4200	4900	5600
16′	2400	3200	4100	4800	5600	6400
17′	2700	3600	4500	5400	6300	7200
18′	3100	4100	5100	6100	7100	8100
19′	3400	4500	5600	6800	7900	9000
20′	3750	5000	6250	7500	8750	10000
21′	4100	5500	6900	8300	9600	11000
22′	4500	6000	7600	9000	10500	12000
23′	5000	6600	8300	10000	11600	13200
24′	5400	7200	9000	10800	12500	14300

BENDING MOMENT IN SLABS

In Foot-Pounds per Foot Width

Simple Span–One Way Type.

Span of Slab in Feet	LOAD PER SQUARE FOOT LIVE PLUS DEAD					
	250	300	350	400	450	500
5′	780	940	1100	1250	1400	1560
6′	1150	1350	1650	1800	2050	2250
7′	1550	1850	2150	2450	2750	3050
8′	2000	2400	2800	3200	3600	4000
9′	2550	3000	3550	4050	4600	5100
10′	3150	3750	4400	5000	5650	6250
11′	3800	4550	5300	6100	6800	7600
12′	4500	5400	6300	7200	8100	9000
13′	5300	6400	7400	8500	9500	10600
14′	6100	7400	8600	9800	11100	12300
15′	7100	8500	9900	11300	12700	14100
16′	8000	9600	11200	12800	14400	16000
17′	9000	10800	12700	14500	16300	18000
18′	10100	12200	14200	16200	18200	20300
19′	11300	13600	15800	18000	20400	22600
20′	12500	15000	17500	20000	22500	25000
21′	13800	16500	19300	22000	24700	27500
22′	15200	18200	21200	24200	27300	30200
23′	16500	19800	23200	26500	29700	33000
24′	18000	21600	25200	28800	32400	36000

BENDING MOMENT IN SLABS

In Foot-Pounds per Foot Width

Simple Span—One Way Type.

Span of Slab in Feet.	LOAD PER SQUARE FOOT Live plus Dead					
	550	600	700	800	900	1000
5′	1720	1875	2200	2500	2820	3125
6′	2500	2700	3150	3600	4050	4500
7′	3400	3700	4300	4900	5500	6150
8′	4400	4800	5600	6400	7200	8000
9′	5370	6100	7100	8100	9100	10100
10′	6870	7500	8750	10000	11250	12500
11′	8300	9100	10600	12100	13600	15100
12′	9900	10800	12600	14400	16200	18000
13′	11600	12700	14800	16900	19000	21100
14′	13500	14700	17200	19600	22000	24500
15′	15500	17000	19600	22500	25400	28100

PROPERTIES OF SLABS.

Slabs of different thicknesses are given from 2½ inches to 18 inches. By the "thickness of a slab" is meant the total thickness including the one half inch of concrete fireproofing on the under side of the rods.

The "depth of the slab" given in the table has been previously explained as the distance from the center of reinforcement to the extreme compression fibre.

The effective depth is given in feet and the tension required, is given for steel figured at a working load of 16000 pounds per square inch.

This moment of resistance is a maximum capacity of the slab under conditions already given, and additional resistance can not be economically obtained by an increase in steel over that called for in column four.

This table is useful in determining the thickness of the slab and the tension required, after having calculated the bending moment in foot pounds.

Example: If a slab has such a span and load as to develop a bending moment of 2600 foot pounds per foot of width, what slab will be required to furnish the proper moment of resistance?

Answer: A slab six inches thick will provide a moment of resistance of 2636 foot pounds per foot of width, and the tension required in the steel will be 7088 pounds; the weight of the slab will be 75 pounds per square foot, and it will contain 0.5 of a cubic foot of concrete.

PROPERTIES OF SLABS.

Per Foot of Width at 500 Pounds extreme Fibre strain on the concrete and 16000 pounds in the Steel

TOTAL THICKNESS OF SLAB. Thickness.	C. of G. Steel From Extreme Comp. Fibre	Effective Depth in Feet	Total Stress in Steel 1350 x D′	Moment of Resistance in Ft. Lbs.	Cu. Ft. Concrete Per □′	Weight of Concrete @ 150 lbs
2½″	1.87″	.133′	2531	336	.21	31.3
3″	2.31″	.164′	3122	511	.25	37.5
3½″	2.81″	.199′	3797	756	.30	43.8
4″	3.31″	.235′	4472	1051	.34	50.0
4½″	3.78″	.268′	5105	1368	.38	56.3
5″	4.28″	.303′	5780	1751	.42	62.5
5½″	4.78″	.339′	6454	2188	.46	68.8
6″	5.25″	.372′	7088	2636	.50	75.0
6½″	5.75″	.407′	7763	3159	.55	81.3
7″	6.20″	.440′	8374	3680	.59	87.5
8″	7.10″	.500′	9597	4832	.67	100.0
9″	8.10″	.575′	10947	6280	.75	112.5
10″	9.01″	.639′	12171	7771	.84	125.0
12″	10.92″	.770′	14744	11404	1.00	150.0
14″	12.78″	.905′	17254	15624	1.17	175.0
16″	14.78″	1.040′	19954	20853	1.34	200.0
18″	16.60″	1.170′	22400	26322	1.50	225.0

MOMENT OF RESISTANCE OF SLABS.

The tables on the following pages give the moment of resistance in the various thicknesses, of slab, ranging from $2\frac{1}{2}''$ to $12''$ total thickness, this thickness including the concrete on the under side of the rods. These tables are to be used in connection with the tables of bending moment in foot pounds already given.

From the theory of the concrete beam already explained it will be seen that the safe capacity of any thickness of slab, is reached when the concrete has been strained to 500 pounds per square inch in the extreme fibre, and that a greater amount of steel placed in the slab than is required to produce this compression is not economical. In these tables the top figure in any column, indicates the maximum moment of resistance in foot pounds, which the slab is capable of resisting at the allowed stresses, and rods spaced closer together than the corresponding distance shown will be of no advantage.

Example: What thickness of slab and what sizes and spacing of bars will give a resistance of 4,900 foot pounds per foot of width?

Answer: An eight-inch slab with $\frac{5}{8}''$ rods $6''$ on centers, or a $9''$ slab with $\frac{3}{4}''$ rods $10''$ on centers, or a $10''$ slab with $\frac{7}{8}''$ rods $14''$ on centers.

It is obvious that the first one is most economical, as the maximum amount of strength is being obtained from a minimum quantity of concrete. For the sake of economy, however, it would be well to use $\frac{3}{4}''$ rods spaced such a distance on centers as to give the same tension as

the $\frac{5}{8}$″ rods 6″ on centers. This may be obtained by referring to table for tensions in rods. The advantage gained is that the price of $\frac{3}{4}$″ rods is slightly less than that of $\frac{5}{8}$″, and that less pieces need be handled, thus reducing the cost of labor. Rods may be spaced within a slab with safety up to a distance on centers equal to double the thickness of the slab, where the "one way" types are used, and for "two-way" types they may be spaced in each direction a distance equal to three times the thickness of the slab, although spacing of about half these amounts is recommended as being better construction.

Where the surface of the slab is finished for a wearing surface, it may be considered as a part of the total thickness of the slab, provided it is placed at the same time as the body so that it is thoroughly bonded together; but if this wearing surface is placed at a later date, it should in no case be considered as giving any strength to the slab.

TWO AND ONE-HALF INCH SLABS.

Moment of Resistance in Foot Pounds for a Width of One Foot.

Diameter of Round Rod		¼″	5/16″	⅜″	
Effective Depth in Feet		.133′	.130′		
Spacing of Rods Unit Strain 16000 lbs.	3½″	336			
	4″	313			
	4½″	278			
	5″	250			
	5½″	227			
	6″	210	319		
	6½″	192	294		
	7″		273		
	7½″		255		

THREE INCH SLABS.

Moment of Resistance in Foot Pounds for a Width of One Foot.

Diameter of Round Rod		¼″	5/16″	⅜″	
Effective Depth in Feet		.168′	.166′	.163′	
Spacing of Rods Unit Strain 16000 lbs.	4″	396			
	4½″	351			
	5″	316	488		
	5½″	287	444		
	6″	263	407		
	6½″	243	375	511	
	7″	226	348	493	
	7½″	211	325	460	
	8″	198	305	431	

THREE AND ONE-HALF INCH SLABS.

Moment of Resistance in Foot Pounds for a Width of One Foot.

Diameter of Round Rod		1/4"	5/16"	3/8"	7/16"
Effective Depth in Feet		.204'	.201'	.199'	.197'
Spacing of Rods Unit Strain 16000 lbs.	4"	481	740		
	4½"	427	657		
	5"	385	591		
	5½"	350	537	756	
	6"	320	493	703	
	6½"		455	649	
	7"		422	602	
	7½"		394	562	757
	8"		370	527	710

FOUR INCH SLABS.

Moment of Resistance in Foot Pounds for a Width of One Foot.

Diameter of Round Rod		1/4"	5/16"	3/8"	7/16"
Effective Depth in Feet		.239'	.236'	.234'	.232'
Spacing of Rods Unit Strain 16000 lbs.	4"	563	868		
	4½"	500	772	1051	
	5"	450	695	993	
	4½"	409	631	901	
	6"	375	579	827	
	6½"		534	763	1030
	7"		492	708	956
	7½"		463	661	892
	8"		434	620	836

FOUR AND ONE-HALF INCH SLABS.

Moment of Resistance in Foot Pounds for a Width of One Foot.

Diameter of Round Rod		5/16″	3/8″	7/16″	1/2″
Effective Depth in Feet		.27′	.27′	.26′	.26′
Spacing of Rods Unit Strain 16000 lbs.	4″	997	1370		
	4½″	887	1267		
	5″	798	1140		
	5½″	725	1036	1370	
	6″	665	950	1284	
	6½″	613	877	1185	
	7″	570	814	1101	
	7½″	532	760	1027	1310
	8″	499	713	963	1248

FIVE INCH SLABS.

Moment of Resistance in Foot Pounds for a Width of One Foot.

Diameter of Round Rod		3/8″	7/16″	1/2′	5/8′
Effective Depth in Feet		.3′	.3′	.3′	.3′
Spacing of Rods Unit Strain 16000 lbs.	4″	1600			
	4½″	1412			
	5″	1271	1751		
	5½″	1170	1583		
	6″	1074	1453		
	6½″	991	1340	1739	
	7″	920	1245	1615	
	7½″	859	1161	1507	
	8″	800	1080	1413	
	9″	706	961	1256	1767

SIX INCH SLABS.

Moment of Resistance in Foot Pounds for a Width of One Foot.

Diameter of Round Rod		3/8"	7/16"	1/2"	5/8"
Effective Depth in Feet		0.37'	0.37'	0.37'	0.36'
Spacing of Rods Unit Strain 16000 lbs.	4"	1961	2698		
	4½"	1742	2400		
	5"	1568	2158	2636	
	5½"	1424	1939	2533	
	6"	1307	1800	2331	
	6½"		1642	2145	
	7"		1542	1996	
	7½"		1423	1859	
	8"		1349	1747	2636
	9"		1200	1553	2356

SEVEN INCH SLABS.

Moment of Resistance in Foot Pounds for a Width of One Foot.

Diameter of Round Rod		3/8"	7/16"	1/2"	5/8"
Effective Depth in Feet		0.45'	0.44'	0.44'	0.44'
Spacing of Rods Unit Strain 16000 lbs.	4"	2385	3174		
	4½"	2119	2822	3684	
	5"	1907	2539	3317	
	5½"	1732	2306	3012	
	6"		2116	2764	
	6½"		1953	2550	
	7"		1814	2368	3623
	7½"			2210	3455
	8"			2073	3239
	9"			1842	2880

EIGHT INCH SLABS.

Moment of Resistance in Foot Pounds for a Width of One Foot.

Diameter of Round Rod		7/16″	1/2″	5/8″	3/4″
Effective Depth in Feet		0.5′	0.5′	0.5′	0.49′
Spacing of Rods Unit Strain 16000 lbs.	4″	3607	4711		
	4½″	3206	4182		
	5″	2885	3764		
	5½″	2620	3423		
	6″	2405	3141	4909	
	6½″		2898	4530	
	7″		2692	4208	
	7½″			3926	
	8″			3681	
	9″			3272	4653

NINE INCH SLABS.

Moment of Resistance in Foot Pounds for a Width of One Foot.

Diameter of Round Rod		7/16″	1/2″	5/8″	3/4″
Effective Depth in Feet		0.60′	0.60′	0.58′	0.58′
Spacing of Rods Unit Strain 16000 lbs.	4″	4328	5653		
	4½″	3848	5024		
	5″	3462	4523		
	5½″	3144	4107	6356	
	6″	2886	3769	5694	
	6½″		3480	5255	
	7″		3230	4881	
	7½″		3014	4555	
	8″		2827	4271	6150
	9″			3796	5466

TEN INCH SLABS.
Moment of Resistance in Foot Pounds for a Width of One Foot.

Diameter of Round Rod		½″	⅝″	¾″	⅞″
Effective Depth in Feet		0.65′	0.63′	0.63′	0.6′
Spacing of Rods Unit Strain 16000 lbs.	4″	6114			
	4½″	5443			
	5″	4900	7421		
	5½″	4450	6742		
	6″	4083	6185		
	6½″	3770	5708		
	7″		5300	7633	
	7½″		4947	7124	
	8″		4638	6678	
	9″		4128	5936	7696

TWELVE INCH SLABS.
Moment of Resistance in Foot Pounds for a Width of One Foot.

Diameter of Round Rod		½″	⅝″	¾″	⅞″
Effective Depth in Feet		0.82′	0.80′	0.80′	0.78′
Spacing of Rods Unit Strain 16000 lbs.	4″	7726	11780		
	4½″	6767	10471		
	5″	6181	9424		
	5½″	5613	8560		
	6″	5141	7854	11310	
	6½″		7249	10438	
	7″		6730	9693	
	7½″		6282	9047	
	8″		5890	8481	11256
	9″			7540	10005

CAPACITIES OF SLABS.

The following tables for capacities of slabs are calculated for simple one-way spans where the bending moment is equal to $\frac{1}{8}WL^2$, W being the total dead and live load per square foot. The thickness of the slab required and the tension in the reinforcement per foot of width, are given.

Example: For a slab of the simple one-way type of reinforcement, having a span of 12 feet, what thickness of slab will be required and what tension will be necessary per foot of width to carry a total dead and live load of 175 pounds per square foot? Answer: The total thickness of the slab is 6.50 inches and the tension required 7,800 pounds per foot of width.

Example: In a square panel 14′x14′ of the simple two-way type of reinforcement, what thickness of slab and what tension per foot of width in each direction will be required to carry a total live and dead load of 500 pounds per square foot? (See discussion of distribution of load and types of reinforcement.)

Answer: 0.5x0.8x500=200 pounds per square foot. The thickness of the slab from the table will be 7.98 inches, or practically 8 inches, and the tension in each direction per foot of width will be 9,750 pounds.

In case the panel is oblong, the coefficients already given are to be used in determining the amount of load which goes in each direction, instead of considering that one-half of it goes each way as above.

THICKNESS OF SLABS IN INCHES AND TENSION IN REINFORCEMENT IN POUNDS

For Various Loads and Spans.

Simple Span—One Way Type.

Live Plus Dead Load Per Square Foot.

Span	75 lbs.	100 lbs.	125 lbs.	150 lbs.	175 lbs.	200 lbs.
5′	2.25″ 2130	2.49″ 2430	2.70″ 2750	2.90″ 3000	3.09″ 3250	3.25″ 3500
6′	2.58″ 2550	2.85″ 2930	3.11″ 3280	3.34″ 3600	3.56″ 3900	3.75″ 4110
7′	2.89″ 2960	3.23″ 3420	3.54″ 3860	3.79″ 4200	4.04″ 4520	4.27″ 4850
8′	3.19″ 3400	3.59″ 3900	3.94″ 4400	4.24″ 4800	4.52″ 5200	4.82″ 5550
9′	3.50″ 3800	3.93″ 4400	4.37″ 4925	4.72″ 5400	5.02″ 5800	5.32″ 6200
10′	3.84″ 4250	4.32″ 4900	4.77″ 5450	5.15″ 6000	5.52″ 6500	5.85″ 6900
11′	4.17″ 4700	4.72″ 5400	5.17″ 6000	5.62″ 6600	6.00″ 7100	6.35″ 7600
12′	4.47″ 5100	5.07″ 5900	5.57″ 6550	6.05″ 7200	6.50″ 7800	6.85″ 8250
13′	4.82″ 5550	5.42″ 6400	6.00″ 7100	6.50″ 7800	6.98″ 8400	7.48″ 9050
14′	5.12″ 6000	5.8″ 6800	6.65″ 7700	6.98″ 8400	7.48″ 9050	7.98″ 9750
15′	5.42″ 6400	6.15″ 7300	6.83″ 8200	7.43″ 9000	7.98″ 9750	8.46″ 10300
16′	5.75″ 6800	6.55″ 7850	7.33″ 8800	7.88″ 9600	8.46″ 10300	9.00″ 11100
17′	6.05″ 7200	6.85″ 8400	7.68″ 9400	8.31″ 10100	8.91″ 11000	9.51″ 11800
18′	6.45″ 7800	7.33″ 8800	8.11″ 9850	8.81″ 10800	9.41″ 11600	10.00″ 12500
19′	6.78″ 8100	7.68″ 9400	8.46″ 10300	9.31″ 11500	9.95″ 12500	10.55″ 13100
20′	7.08″ 8550	8.06″ 9850	8.91″ 11000	9.75″ 12000	10.45″ 13000	11.10″ 13900
21′	7.33″ 8800	8.41″ 10200	9.31″ 11500	10.15″ 12500	10.85″ 13500	11.55″ 14500
22′	7.68″ 9400	8.81″ 10800	9.75″ 12000	10.55″ 13100	11.37″ 14100	12.00″ 15100
23′	8.00″ 9850	9.11″ 11200	10.15″ 12500	11.10″ 13900	11.97″ 15100	12.67″ 16000
24′	8.31″ 10100	9.51″ 11800	10.55″ 13100	11.50″ 14400	12.27″ 15400	13.00″ 16500

THICKNESS OF SLABS IN INCHES AND TENSION IN REINFORCEMENT IN POUNDS

For Various Loads and Spans.

Simple Span—One Way Type.

Live Plus Dead Load Per Square Foot.

Span	250 lbs.	300 lbs.	350 lbs.	400 lbs.	450 lbs.	500 lbs.
5′	3.53″ 3850	3.84″ 4250	4.09″ 4600	4.29″ 4860	4.56″ 5200	4.76″ 5500
6′	4.17″ 4700	4.47″ 5100	4.87″ 5600	5.07″ 5900	5.37″ 6300	5.57″ 6600
7′	4.72″ 5400	5.12″ 6000	5.42″ 6400	5.77″ 6850	6.11″ 7200	6.40″ 7650
8′	5.28″ 6200	5.70″ 6800	6.15″ 7300	6.55″ 7800	6.87″ 8300	7.28″ 8800
9′	5.90″ 7000	6.36″ 7800	6.85″ 8250	7.28″ 8800	7.71″ 9350	8.00″ 9800
10′	6.50″ 7800	7.03″ 8500	7.58″ 9200	8.00″ 9850	8.50″ 10400	8.88″ 11100
11′	7.05″ 8550	7.71″ 9300	8.26″ 10100	8.81″ 10800	9.24″ 11500	9.71″ 12000
12′	7.68″ 9400	8.31″ 10100	8.91″ 11000	9.51″ 11750	10.05″ 12500	10.58″ 13100
13′	8.26″ 10100	9.01″ 11000	9.61″ 12000	10.25″ 12600	10.85″ 13500	11.40″ 14500
14′	8.81″ 10800	9.61″ 12000	10.35″ 13000	10.90″ 13700	11.65″ 14600	12.20″ 15300
15′	9.41″ 11600	10.25″ 12600	11.05″ 13800	11.75″ 14700	12.43″ 15600	13.08″ 16500
16′	10.00″ 12400	10.90″ 13550	11.68″ 14550	12.48″ 15700	13.20″ 16600	13.88″ 17500
17′	10.55″ 13000	11.45″ 14450	12.48″ 15750	13.20″ 16600	13.94″ 17500	14.64″ 18500
18′	11.15″ 14000	12.18″ 15250	13.08″ 16500	13.94″ 17500	14.74″ 18550	
19′	11.75″ 14600	12.88″ 16200	13.79″ 17400	14.64″ 18500		
20′	12.28″ 15300	13.44″ 17000	14.54″ 18300			
21′	12.87″ 16200	14.14″ 18000	15.14″ 19250			
22′	13.48″ 17000	14.74″ 18600				
23′	14.14″ 18000	15.34″ 19500				
24′	14.64″ 18500	16.10″ 20500				

THE DESIGN OF BEAMS.

Reinforced concrete beams are similar in principle to reinforced slabs already described. The general principle is that a truss must be formed in which the steel resists the tension stresses while the compression stresses are cared for by the concrete.

When a beam is required to carry a concentrated load, it must be specially solved according to the condition, to determine the bending moment which must be resisted. When, however, a uniform load is to be carried the bending moment may either be figured, or it may be taken from the tables given on the following pages.

The designer of course understands that whether the beam carries a uniform or a concentrated load, it must have a moment of resistance equal to or greater than, the bending moment caused by the load.

Tables are given on the following pages showing the moments of resistance of beams having various depths, and of the standard four, six and eight rod types.

After having solved for the bending moment and having selected the type and depth of beam required to resist this bending moment, there is not much to do but to detail the various rods according to the standard types here shown.

As a guide in selecting the proper beam it might be noted that as a rule, a beam should have a height of not less than one inch for each foot of span, and that one and one-half inches is

better, the height being measured from the top of the slab to the extreme bottom. The width of the beam should be such as to amply imbed the rods and give a proper working space in the forms for proper construction. In general, eight, ten and twelve inch widths are recommended for the four, six and eight rod types with additional widths for very heavy reinforcements.

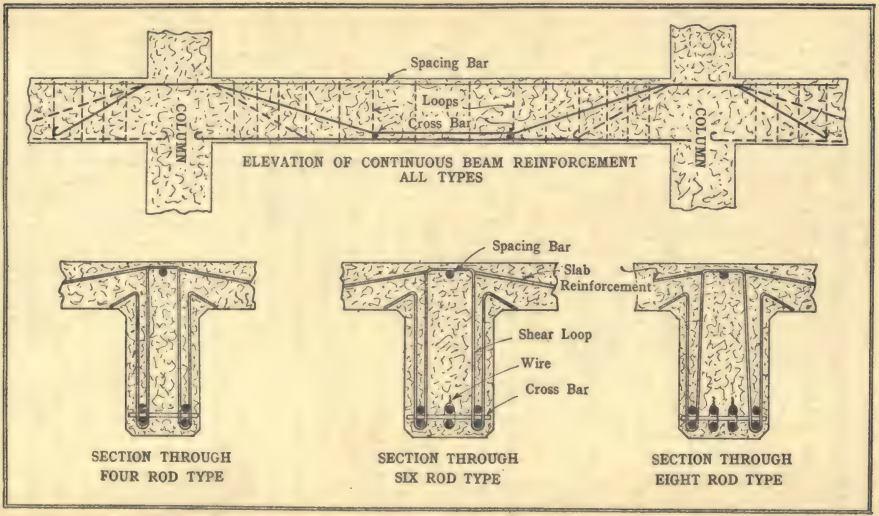
For general use the six rod type of beams is preferable, for there are not so many rods to handle as in the eight rod type and the rods are of a more convenient size than in many cases would be required in the four rod type. Rods of short lengths and large diameters should not be used, as the surface being less in proportion to the cross sectional area, the adhesion is not as large in proportion to the tensile strength. The designer should keep in mind the table shown on another page, where is given the length, which a rod must be imbedded to develop a tensile strain of 16000 pounds per square inch without requiring an adhesion of more than 50 pounds per square inch of surface. This table as applied to a beam or slab with its maximum strain at the middle would limit the span in which a rod of any diameter might be used by indicating the least distance from the center of the span to the end of the rod. Although hooks certainly add considerable to the firmness with which a bar is imbedded in a body of concrete, by very materially increasing the friction, they should not be depended upon to any great extent but should be considered rather as adding to the factor of safety of the structure.

In very heavily reinforced beams, the total stress may become so great in the compression

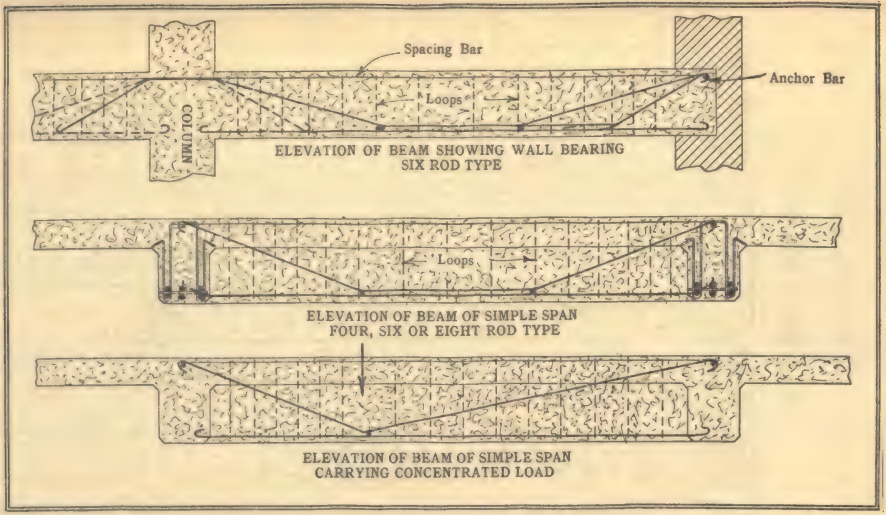
chord as to exceed the allowable working load. This is especially true where the beam is connected with a very thin slab which affords little assistance as a tee section, or in beams of rectangular section acting independent of any slab. In such cases it is necessary for the designer to increase the strength of the compression chord by longitudinal reinforcement or by means of looping. The latter method suggests more possibilities but the subject has been so slightly investigated at the present time, that no attempt is made here to standardize the method of construction.

Attention is called to the various points of the standard beams as here detailed. The cross bars, spacing bar, and loops all have their parts to perform. The spacing bar in particular is a necessity in maintaining the position of the slab reinforcement and should not be omitted under any consideration.

The size and spacing of beam loops here tabulated are entirely arbitrary. It is considered that these loops are provided to tie the beam to the slab acting more as a resistance to horizontal shear than to vertical tensile stresses in a reinforced concrete beam, which are in reality tensile stresses, are amply provided, in these standards, by the arrangement of the reinforceing rods as they bend up and over the point of support. Loops consequently are used as a resistance to horizontal shear and as a means of holding the reinforcement in place during construction. They should be placed closer together near the ends of the beam but on an average a loop should be supplied for each lineal oot of beam.



STANDARD BEAM REINFORCEMENT.



STANDARD BEAM REINFORCEMENT.

BENDING MOMENT IN BEAMS.

In Foot-Pounds

Simple Span $M = \frac{1}{8} WL$.

SPAN	UNIFORM LOAD IN POUNDS—LIVE PLUS DEAD.						
	5000	6000	7000	8000	9000	10000	15000
5′	3100	3800	4400	5000	5600	6300	9400
6′	3800	4500	5300	6000	6700	7500	11300
7′	4400	5300	6200	7000	7900	8800	13200
8′	5000	6000	7000	8000	9000	10000	15000
9′	5600	6800	7900	9000	10200	11200	17000
10′	6200	7500	8800	10000	11200	12500	18700
11′	6900	8200	9600	11000	12300	13200	20500
12′	7500	9000	10500	12000	13500	15000	22500
13′	8200	9800	11500	13000	14700	16200	24500
14′	8800	10500	12300	14000	15700	17500	26200
15′	9400	11200	13200	15000	17000	18700	28000
16′	10000	12000	14000	16000	18000	20000	30000
17′	10600	12700	15000	17000	19000	21200	32000
18′	11300	13500	15700	18000	20200	22500	34000
19′	11700	14200	16600	19000	21400	23700	35500
20′	12500	15000	17500	20000	22500	25000	37500
21′		15700	18300	21000	23000	26000	39500
22′		16500	19200	22000	24500	27500	41000
23′			20000	23000	25700	28700	43000
24′			21000	24000	27000	30000	45000
26′				26000	29300	32500	49000
28′				28000	31500	35000	52500
30′					33800	37500	56000
35′						44000	66000
40′							75000
45′							
50′							

BENDING MOMENT IN BEAMS.

In Foot-Pounds.

Simple Span M-⅛ WL.

SPAN	UNIFORM LOAD IN POUNDS—LIVE PLUS DEAD.					
	20000	25000	30000	35000	40000	45000
5′	12500	15600	1880			
6′	15000	18800	22500			
7′	17500	22000	26200	31000		
8′	20000	25000	30000	35000		
9′	22500	28000	34000	39000	45000	
10′	25000	31000	37500	43500	50000	56000
11′	27500	34000	41000	48000	55000	62000
12′	30000	37500	45000	52500	60000	68000
13′	32500	41000	49000	57000	65000	73000
14′	35000	44000	53000	61000	70000	78000
15′	37500	47000	56000	66000	75000	84000
16′	40000	50000	60000	70000	80000	90000
17′	42500	53000	64000	74000	85000	96000
18′	45000	56000	68000	79000	90000	102000
19′	47500	59000	71000	83000	95000	107000
20′	50000	62500	75000	87500	100000	112500
21′	52500	66000	79000	92000	105000	118000
22′	55000	69000	83000	96000	110000	124000
23′	57500	72000	86000	100000	115000	128000
24′	60000	75000	90000	105000	120000	135000
26′	65000	81000	98000	114000	130000	147000
28′	70000	87000	105000	122000	140000	157000
30′	75000	94000	113000	131000	150000	168000
35′	88000	110000	130000	152000	175000	196000
40′	100000	125000	150000	175000	200000	225000
45′	113000	140000	168000	196000	225000	252000
50′	125000	156000	187000	220000	250000	280000

BENDING MOMENT IN BEAMS.

In Foot-Pounds

Simple Span M-⅛ WL.

SPAN	UNIFORM LOAD IN POUNDS—LIVE PLUS DEAD.					
	50000	60000	70000	80000	90000	100000
10′	62000	75000				
11′	69000	83000	97000	110000		
12′	75000	90000	105000	120000	135000	150000
13′	81000	98000	115000	130000	146000	162000
14′	88000	105000	122000	140000	158000	175000
15′	94000	113000	132000	150000	170000	187000
16′	100000	120000	140000	160000	180000	200000
17′	107000	127000	150000	170000	192000	213000
18′	113000	135000	157000	180000	203000	225000
19′	118000	142000	166000	190000	213000	237000
20′	125000	150000	175000	200000	225000	250000
21′	131000	157000	184000	210000	235000	262000
22′	137000	165000	192000	220000	246000	275000
23′	143000	172000	200000	230000	257000	286000
24′	150000	180000	210000	240000	270000	300000
26′	162000	194000	227000	260000	292000	325000
28′	175000	210000	244000	280000	312000	350000
30′	187000	225000	261000	300000	335000	375000
35′	218000	262000	305000	350000	390000	435000
40′	250000	300000	350000	400000	450000	500000
45′	280000	336000	392000	450000	505000	560000
50′	312000	375000	435000	500000	560000	625000

FOUR-ROD TYPE OF BEAM.

MOMENT OF RESISTANCE.

In Foot Pounds.

Round Rods			4-½″	4-⅝″	4-¾″	4-⅞″	4-1″	4-1⅛″
Total Area of Rods			.7854 Sq. In.	1.227 Sq. In.	1.767 Sq. In.	2.405 Sq. In.	3.1416 Sq. In.	3.976 Sq. In.
Tension Value @ 16000 Pounds Per Square Inch.			12500 Pounds	20300 Pounds	28300 Pounds	38800 Pounds	50000 Pounds	64000 Pounds
HEIGHT OF BEAM AND EFFECTIVE DEPTH.	11″	.64′	7000	11400	15800	21700		
	12″	.71′	8000	13000	18000	24700		
	13″	.78′	8850	14400	20000	27500	35500	
	14″	.85′	9700	15800	22000	30000	39000	
	15″	.92′	10600	17300	24000	33000	42500	54500
	16″	.99′	11500	18600	26000	35500	46500	58500
	17″	1.06′	12400	20100	28000	38500	50000	64000
	18″	1.13′	13200	21600	30000	41000	53000	68000
	19″	1.20′	14000	23000	32000	44000	56500	73000
	20″	1.27′	15000	24400	34000	46500	60000	77000
	21″	1.34′	15800	26000	36000	49500	63500	81000
	22″	1.40′		27000	37800	52000	67000	86000
	23″	1.48′		28300	39500	54000	70000	89000
	24″	1.55′			42000	57500	74000	95000
	25″	1.62′			43500	60000	77500	99000
	26″	1.69′			45500	62500	81000	104000

SIX-ROD TYPE OF BEAM

MOMENT OF RESISTANCE.

In Foot Pounds.

Round Rods			6-$\frac{5}{8}$″	6-$\frac{3}{4}$″	6-$\frac{7}{8}$″	6-1″	6-1$\frac{1}{8}$″	6-1$\frac{1}{4}$″
Total Area of Rods			1.8408 Sq. In.	2.6508 Sq. In.	3.6078 Sq. In.	4.7124 Sq. In.	5.964 Sq. In.	7.3632 Sq. In.
Tensile Value @ 16000 Pounds Per Square Inch.			29400 Pounds	42400 Pounds	57700 Pounds	75400 Pounds	95400 Pounds	117800 Pounds
HEIGHT OF BEAM AND EFFECTIVE DEPTH.	16″	.99′	27000	39000	53100			
	17″	1.06′	29100	42000	57100			
	18″	1.13′	31100	45000	61200	80000		
	19″	1.20′	33200	48000	65200	85200		
	20″	1.27′	35300	50900	69200	90500	115000	
	21″	1.34′	37300	53900	73200	95700	121000	
	22″	1.40′	39400	56800	77300	101000	128000	158000
	23″	1.48′	41200	59400	80800	105500	133000	165000
	24″	1.55′	43500	62700	85400	111600	141000	174000
	25″	1.62′	45600	65720	89500	116800	148000	182600
	26″	1.69′		68700	93500	122000	155000	191000
	27″	1.76′		71600	97500	127400	161200	199000
	28″	1.83′			101500	132700	168000	207000
	29″	1.90′			105600	138000	174500	216000
	30″	1.97′				143300	181000	224000
	31″	2.04′				148000	188000	232000

EIGHT-ROD TYPE OF BEAM.

MOMENT OF RESISTANCE.

In Foot Pounds.

Round Rods			8-$\frac{5}{8}$″	8-$\frac{3}{4}$″	8-$\frac{7}{8}$″	8-1″	8-1$\frac{1}{8}$″	8-1$\frac{1}{4}$″
Total Area of Rods			2.454 Sq. In.	3.534 Sq. In.	4.810 Sq. In.	6.283 Sq. In.	7.952 Sq. In.	9.818 Sq. In.
Tensile Value @ 16000 Pounds Per Square Inch.			39200 Pounds	56500 Pounds	77000 Pounds	100500 Pounds	127000 Pounds	157000 Pounds
HEIGHT OF BEAM AND EFFECTIVE DEPTH.	22″	1.40′	52500	75700	103200			
	23″	1.48′	55000	79100	107800	140700		
	24″	1.55′	58000	83600	114000	148700		
	25″	1.62′	60700	87500	119300	155800	197000	
	26″	1.69′	63500	91500	124700	162800	205700	
	27″	1.76′	66300	95500	130100	170000	214600	265300
	28″	1.83′	69000	99500	135500	176900	223500	276300
	29″	1.90′	71700	103400	140900	183900	232400	287300
	30″	1.97′		108200	146300	191000	241300	298300
	31″	2.04′		111300	151700	198000	250200	309300
	32″	2.10′		115300	157000	205000	259000	320000
	33″	2.17′		118700	161700	211000	266700	330000
	34″	2.26′			167000	218000	275600	340700
	35″	2.35′			174000	227100	287000	354800
	36″	2.40′			181000	236200	298500	369000
	37″	2.47′			184800	241000	304800	376800

SHEAR LOOPS FOR BEAMS.

Total Height of Beam to top of slab	Size of Bar From Which Loop is Made.	Length Required to Make One Loop.	Weight of One Loop in Pounds
11″	¼″ Round	3′-2″	0.52
12″	"	3′-6″	0.60
13″	"	3′-10″	0.64
14″	"	4′-2″	0.70
15″	"	4′-6″	0.75
16″	5/16″ Round	4′-10″	1.26
17″	"	5′-2″	1.35
18″	"	5′-6″	1.44
19″	"	5′-10″	1.52
20″	"	6′-2″	1.61
21″	"	6′-6″	1.70
22″	"	6′-10″	1.78
23″	"	7′-2″	1.87
24″	"	7′-6″	1.96
25″	"	7′-10″	2.04
26″	"	8′-2″	2.13
27″	"	8′-6″	2.22
28″	"	8′-10″	2.30
29″	"	9′-2″	2.39
30″	⅜″ Round	9′-6″	3.56
31″	"	9′-10″	3.68
32″	"	10′-2″	3.81
33″	"	10′-6″	3.93
34″	"	10′-10″	4.06
35″	"	11′-2″	4.18
36″	"	11′-6″	4.31
37″	"	11′-10″	4.44

COLUMNS:

At the present time, nothing in the field of reinforced concrete is creating so much interest as hooped concrete columns.

Although many have made, and are still making tests, in the effort to discover the laws governing the design of hooped concrete columns, no one has done so much as Considere, the French engineer who made a great number of tests and gave us about the only rules we have at present for the solution of hooped concrete.

Considere found that in addition to adding great compressive resistance to the concrete, hooping gives it an element of toughness, not given by longitudinal reinforcement. One column, $5\frac{1}{2}$ inches in diameter was bent to a radius of curvature of only 23.6 inches, without causing cracks in the concrete. No column with longitudinal reinforcement exclusively would do this.

Another feature which is certainly of great advantage is that properly designed hooped concrete columns give ample warning before failure.

The reason for this is self evident. When hooped concrete fails by crushing, the failure takes place by the spalling off of the concrete between the hoops. This spalling off, if the hoops are close enough together, will not reach very deeply into the column and a greatly increased load will be subsequently carried before failure.

No such warning as this is given by columns longitudinally reinforced, for as soon as the load has become great enough to cause a crushing of the concrete, the longitudinal rods will buckle out between the binders, which allows the con-

crete to bulge laterally and failure is instantaneous.

It is for this reason that these standards have substituted hooped concrete columns for those longitudinally reinforced.

Considere recommends the spacing of hoops or spirals at from one-seventh to one-tenth the diameter when longitudinal rods are added. For these standards the same spacing is used for all diameters for the practical reason that manufacture is thereby simplified. Furthermore, if the spacing in the large columns was as much as one-seventh of the diameter, the size of the metal used in the spiral would be exceedingly inconvenient to handle.

For the calculation of the compressive resistance of hooped concrete not subject to flexure, Considere has given the rules quoted below.

"The compressive resistance of a hooped member exceeds the sum of the following three elements:

1. Compressive resistance of the concrete without reinforcing.
2. Compressive resistance of the longitudinal rods stressed to their elastic limit,
3. Compressive resistance which would have been produced by the imaginary longitudinals at the elastic limit of the hooping metal, the volume of the imaginary longitudinals being taken as 2.4 times that of the hooping."

There are some practical difficulties in adopting the actual existing conditions to the rules stated.

For instance existing laws do not recognize the high compressive resistance of hooped concrete, and even if the inspectors do acknowledge its ultimate strength, they will not permit its use except with a very large factor of safety. Furthermore even if high stresses were permitted, it does not seem wise with the present lack of knowledge of the subject, to take advantage of the high stresses which possibly may be attained. On the other hand, steel such as is found in the open market is a material of very well defined qualities, the working loads are pretty definitely defined and a factor of safety is not required to be so large as for concrete.

Until hooped concrete columns have been so thoroughly tested as to be no longer an experiment, it seems advisable to use a factor of safety of at least five on a column without longitudinal rods. Where longitudinal rods, however make up a considerable portion of the strength of the column it seems a needless waste of material to use a factor of safety larger than three inside of the elastic limit.

If we assume that a concrete which would crush at 2000 pounds per square inch without hooping, were given such an amount of hooping that the compressive resistance were increased to 4000 pounds per square inch, the safe working load then, would be 800 pounds per square inch, allowing a factor of safety of five. If longitudinal steel rods were used having an elastic limit of about 30,000 pounds per square inch, the safe working load, at a factor of safety of three, would be 10,000 pounds per square inch.

Although the coefficient of elasticity of hooped concrete is not as yet definitely determin-

ed for the various mixtures, still it is often assumed to be about one-twelfth of that of steel. It will be noticed that a working load on longitudinal bars as above assumed is just twelve and one-half times as large as the load assumed upon the concrete, hence the assumption of these working loads is not much at variance with common practice.

For the calculation of the tables given in these standards therefore the following assumptions have been made:

Hooped concrete columns having an ultimate compressive strength of 4000 pounds per square inch, and a working load of 800 pounds per square inch, may be produced by considering that the concrete, before hooping, has a compressive value of 2000 pounds per square inch, and that an additional 2000 pounds compressive value may be added by hooping with a spiral of high carbon wire having an elastic limit of not less than 80,000 pounds per square inch, a spacing of 1½ inches for 10 inch spirals and larger, and a volume equal to ten twenty-fourths of the imaginary longitudinals which, at a compression of 80,000 pounds per square inch, are equivalent to 2000 pounds per square in. on the cross sectional area of the concrete within the spiral.

Fireproofing 1½″ thick is to be allowed for columns by making the outside dimensions of the columns 3 inches greater than the diameter of the spiral hooping.

Concrete on the outside of spiral hooping is not to be considered as contributing any strength to the column.

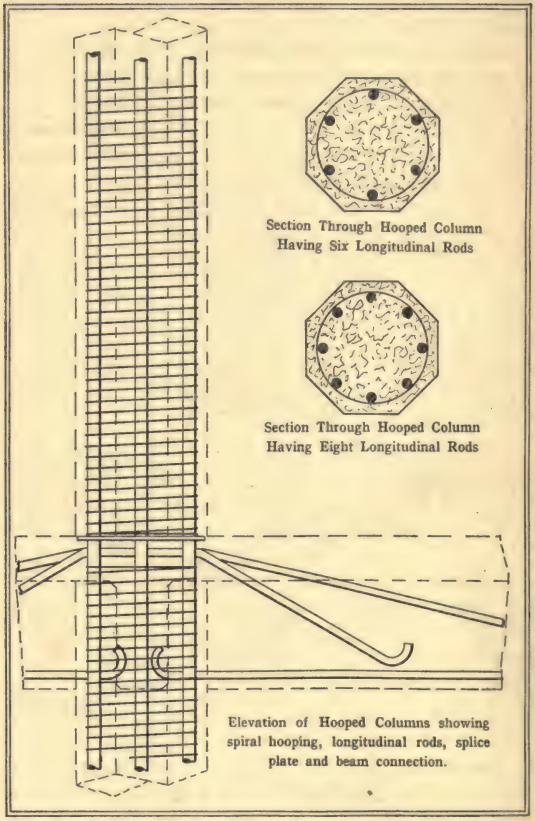
Hooped concrete columns may be increased in capacity by the addition of steel bars on the

inside of the spiral, these bars having an elastic limit of not less than 30,000 pounds per square inch and a working load of 10,000 pounds per square inch.

All concrete for columns is to be mixed in the proportion of one part of Portland cement, to 2½ parts of sand to 4 parts of broken stone, and sufficient water to allow thorough contact with the reinforcement but not so as to separate from the cement sand and stone.

All steel bars for longitudinal reinforcing are to have square ends for bearing on the steel base and cap plates and where bars are 1½″ in diameter or larger, they are to be milled or ground square and to exact lengths for bearing at both ends. This is a provision which has heretofore been sorely neglected but which is just as important as the proper bearing in structural steel or cast iron columns.

Bearing plates are to be provided for all columns at the footings, of not less than the sizes called for in the tables for footings, and splices are to be made in columns at the level of the top of the floor slabs, the column above resting on a steel plate of the same dimensions as the column, and which has a firm bearing on the longitudinal bars of the column below and is grouted into place so as to come into direct contact with the concrete over its entire area. Through the center of each plate a hole is to be provided through which a tie is made between the two columns by the insertion of a one inch round bar three feet long which is provided with a hook on each end for anchorage.


Section Through Hooped Column
Having Six Longitudinal Rods
Section Through Hooped Column
Having Eight Longitudinal Rods
Elevation of Hooped Columns showing
spiral hooping, longitudinal rods, splice
plate and beam connection.

DETAILS OF HOOPED COLUMNS.

TEN INCH COLUMNS.

Spiral 7 Inch Diameter, No. 6 Wire, 1½ Inch Pitch. Concrete Inside of Spiral 800 Pounds per Square Inch, Longitudinal Steel 10,000 Pounds per Square Inch.

LONGITUDINAL ROUND BARS.				Safe Load in Pounds For Column at Height Given	
No. Required	Diameter in Inches	Total Area in Square In.	Total Weight Per Foot in Lbs		
4	½″	0.78	2.66	10′	37000
4	⅝″	1.20	4.16	10′	41000
4	¾″	1.76	6.01	10′	46000
4	⅞″	2.40	8.18	12′	52000
4	1 ″	3.14	10.68	12′	58000
4	1⅛″	3.97	13.52	12′	66000
4	1¼″	4.90	16.69	14′	75000
4	1⅜″	5.94	20.19	14′	84000
4	1½″	7.06	24.03	14′	94000

TWELVE INCH COLUMNS.

Spiral 9 Inch Diameter, No. 5 Wire, 1½ Inch Pitch, Concrete Inside of Spiral 800 Pounds per Square Inch. Longitudinal Steel 10,000 Pounds per Square Inch.

LONGITUDINAL ROUND BARS.				Safe Load in Pounds For Column at Height Given	
No. Required	Diameter in Inches	Total Area in Square in.	Total Weight Per Foot in Lbs		
6	½″	1.17	4.00	10′	63000
6	⅝″	1.83	6.24	10′	69000
6	¾″	2.64	9.01	12′	76000
6	⅞″	3.60	12.24	12′	85000
6	1 ″	4.71	16.00	14′	95000
6	1⅛″	5.96	20.40	14′	106000
6	1¼″	7.36	25.04	14′	120000
6	1⅜″	8.91	30.30	16′	133000
6	1½″	10.60	36.05	16′	149000

FOURTEEN INCH COLUMNS.

Spiral 11 Inch Diameter, No. 3 Wire, 1½ Inch Pitch. Concrete Inside of Spiral, 800 Pounds per Square Inch. Longitudinal Steel 10,000 Pounds per Square Inch.

LONGITUDINAL ROUND BARS.				Safe Load in Pounds For Column at Height Given	
No. Required	Diameter in Inches	Total Area in Square In.	Total Weight Per Foot in Lbs		
6	⅝″	1.83	6.24	12′	93000
6	¾″	2.64	9.01	12′	100000
6	⅞″	3.60	12.24	14′	109000
6	1 ″	4.71	16.00	14′	119000
6	1⅛″	5.96	20.40	16′	130000
6	1¼″	7.36	25.04	16′	143000
6	1⅜″	8.91	30.30	16′	167000
6	1½″	10.60	36.05	18′	173000
6	1⅝″	12.42	42.30	18′	190000
6	1¾″	14.43	49.07	18′	208000
6	1⅞″	16.56	56.34	20′	228000
6	2 ″	18.85	64.08	20′	249000

SIXTEEN INCH COLUMNS.

Spiral 13 Inch Diameter, No. 2 Wire, 1½ Inch Pitch. Concrete Inside of Spiral, 800 Pounds per Square Inch. Longitudinal Steel 10,000 Pounds Square Inch.

LONGITUDINAL ROUND BARS.				Safe Load in Pounds For Column at Height Given	
No. Required	Diameter in Inches	Total Area in Square In.	Total Weight Per Foot in Lbs		
8	⅝″	2.40	8.32	14′	128000
8	¾″	3.52	12.02	14′	138000
8	⅞″	4.81	16.35	14′	150000
8	1 ″	6.28	21.36	16′	163000
8	1⅛″	7.95	27.03	16′	179000
8	1¼″	9.81	33.38	16′	197000
8	1⅜″	11.88	40.38	18′	214000
8	1½″	14.13	48.06	18′	236000
8	1⅝″	16.59	56.41	20′	259000
8	1¾	19.24	65.42	20′	283000
8	1⅞″	22.04	75.10	22′	308000
8	2″	25.13	85.44	22′	338000

EIGHTEEN INCH COLUMNS.

Spiral 15 Inch Diameter, No. 1 Wire, 1½ Inch Pitch. Concrete Inside of Spiral 800 Pound per Square Inch. Longitudinal Steel 10,000 Pounds per Square Inch.

LONGITUDINAL ROUND BARS.				Safe Load in Pounds For Column at Height Given	
No. Required	Diameter in Inches	Total Area in Square In.	Total Weight Per Foot in Lbs.		
8	¾″	3.53	12.02	16′	173000
8	1 ″	6.28	21.36	18′	198000
8	1⅛″	7.95	27.03	20′	213000
8	1¼″	9.81	33.38	24′	231000
8	1⅜″	11.88	40.38	26′	249000
8	1½″	14.13	48.06	30′	271000
8	1⅝″	16.59	56.41	30′	294000
8	1¾″	19.24	65.42	30′	318000
8	1⅞″	22.04	75.10	30′	344000
8	2 ″	25.13	85.44	30′	373000
8	2⅛″	28.37	96.48	30′	402000
8	2¼″	31.81	108.16	30′	433000
8	2⅜″	35.44	120.56	30′	485000
8	2½″	39.26	132.35	30′	502000

TWENTY INCH COLUMNS.

Spiral 17 Inch Diameter, 5-16 Inch Wire, 1½ Inch Pitch. Concrete Inside of Spiral 800 Pounds per Square Inch. Longitudinal Steel 10,000 Pounds per Square Inch.

LONGITUDINAL ROUND BARS.				Safe Load in Pounds For Column at Height Given	
No. Required	Diameter in Inches	Total Area in Square In.	Total Weight Per Foot in Lbs.		
8	¾″	3.53	12.02	18′	213000
8	1 ″	6.28	21.36	20′	238000
8	1¼″	9.81	33.38	24′	271000
8	1⅜″	11.88	40.38	28′	289000
8	1½″	14.13	48.06	30′	310000
8	1⅝″	16.59	56.41	32′	333000
8	1¾″	19.24	65.42	32′	358000
8	1⅞″	22.04	75.10	32′	383000
8	2 ″	25.13	85.44	32′	412000
8	2⅛″	28.37	96.48	32′	442000
8	2¼″	31.81	108.16	32′	473000
8	2⅜″	35.44	120.56	32′	506000
8	2½″	39.26	133.52	32′	542000
8	2⅝″	43.28	147.20	32′	579000
8	2¾″	47.52	161.60	32′	618000
8	2⅞″	51.92	176.56	32′	658000
8	3 ″	56.54	192.24	32′	701000

TWENTY-TWO INCH COLUMNS.

Spiral 19 Inch Diameter, 5-16 Inch Wire, 1½ Inch Pitch. Concrete Inside of Spiral 800 Pounds per Square Inch. Longitudinal Steel 10,000 Pounds per Square Inch.

LONGITUDINAL ROUND BARS.				Safe Load in Pounds For Column at Height Given	
No. Required	Diameter in Inches	Total Area in Square In.	Total Weight Per Foot in Lbs.		
12	¾″	5.30	18.02	20′	275000
12	1 ″	9.42	22.04	22′	313000
12	1¼″	14.72	50.08	24′	362000
12	1⅜″	17.82	60.58	28′	390000
12	1½″	21.20	72.09	32′	421000
12	1⅝″	24.84	84.61	36′	450000
12	1¾″	28.86	98.14	40′	492000
12	1⅞″	33.12	112.65	40′	530000
12	2 ″	37.68	128.16	40′	573000
12	2⅛″	42.55	144.72	40′	618000
12	2¼″	47.71	162.24	40′	665000
12	2⅜″	53.16	180.84	40′	715000
12	2½″	58.89	200.28	40′	768000

TWENTY-FOUR INCH COLUMNS.

Spiral 21 Inch Diameter, ⅜ Inch Wire, 1½ Inch Pitch. Concrete Inside of Spiral 800 Pounds per Square Inch. Longitudinal Steel 10,000 Pounds per Square Inch.

LONGITUDINAL ROUND BARS.				Safe Load in Pounds For Column at Height Given	
No. Required	Diameter in Inches	Total Area in Square In.	Total Weight Per Foot in Lbs.		
12	¾″	5.30	18.02	22′	322000
12	1 ″	9.42	22.04	24′	360000
12	1¼″	14.72	50.08	26′	409000
12	1⅜″	17.82	60.58	28′	437000
12	1½″	21.20	72.09	34′	468000
12	1⅝″	24.84	84.61	38′	497000
12	1¾″	28.86	98.14	42′	539000
12	1⅞″	33.12	112.65	42′	577000
12	2 ″	37.68	128.16	42′	620000
12	2⅛″	42.55	144.72	42′	665000
12	2¼″	47.71	162.24	42′	712000
12	2⅜″	53.16	180.84	42′	762000
12	2½″	58.89	200.28	42′	815000
12	2⅝″	64.93	220.80	42′	871000
12	2¾″	71.26	242.40	42′	929000

TWENTY-SIX INCH COLUMNS.

Spiral 23 Inch Diameter, $\frac{3}{8}$ Inch Wire, $1\frac{1}{2}$ Inch Pitch. Concrete Inside of Spiral 800 Pounds per Square Inch. Longitudinal Steel 10,000 Pounds per Square Inch.

LONGITUDINAL ROUND BARS.				Safe Load in Pounds For Column at Height Given	
No. Required	Diameter in Inches	Total Area in Square In.	Total Weight Per Foot		
12	$\frac{3}{4}$″	5.30	18.02	24′	376000
12	1 ″	9.42	22.04	26′	414000
12	$1\frac{1}{4}$″	14.72	50.08	28′	463000
12	$1\frac{3}{8}$″	17.82	60.58	30′	492000
12	$1\frac{1}{2}$″	21.20	72.09	36′	523000
12	$1\frac{5}{8}$″	24.84	84.61	40′	551000
12	$1\frac{3}{4}$″	28.86	98.14	44′	593000
12	$1\frac{7}{8}$″	33.12	112.65	44′	631000
12	2 ″	37.68	128.16	44′	674000
12	$2\frac{1}{8}$″	42.55	144.72	44′	719000
12	$2\frac{1}{4}$″	47.71	162.24	44′	767000
12	$2\frac{3}{8}$″	53.16	180.84	44′	817000
12	$2\frac{1}{2}$″	58.89	200.28	44′	870000
12	$2\frac{5}{8}$″	64.93	220.80	44′	925000
12	$2\frac{3}{4}$″	71.26	242.40	44′	984000
12	$2\frac{7}{8}$″	77.88	264.84	44′	1044000
12	3 ″	84.72	288.96	44′	1107000

TWENTY-EIGHT INCH COLUMNS.

Spiral 25 Inch Diameter, ⅜ Inch Wire, 1½ Inch Pitch. Concrete Inside of Spiral 800 Pounds per Square Inch. Longitudinal Steel 10,000 Pounds per Square Inch.

LONGITUDINAL ROUND BARS.				Safe Load in Pounds For Column at Height Given	
No. Required	Diameter in Inches	Total Area in Square In.	Total Weight Per Foot		
12	¾″	5.30	18.02	26′	436000
12	1 ″	9.42	22.04	28′	474000
12	1¼″	14.72	50.08	30′	523000
12	1⅜″	17.82	60.58	32′	552000
12	1½″	20.20	72.09	38′	583000
12	1⅝″	24.84	84.61	42′	611000
12	1¾″	28.86	98.14	46′	653000
12	1⅞″	33.12	112.65	50′	691000
12	2 ″	37.68	128.16	50′	734000
12	2⅛″	42.55	144.72	50′	779000
12	2¼″	47.71	162.24	50′	828000
12	2⅜″	53.16	180.84	50′	877000
12	2½″	58.89	200.28	50′	930000
12	2⅝″	64.93	220.80	50′	985000
12	2¾″	71.26	242.40	50′	1043000
12	2⅞″	77.88	264.84	50′	1104000
12	3 ″	84.72	288.96	50′	1167000
12	3⅛″	92.04	312.96	50′	1235000
12	3¼″	99.54	338.40	50′	1304000
12	3⅜″	107.35	365.04	50′	1375000
12	3½″	115.44	391.52	50′	1450000

FOOTINGS.

Reinforced concrete footings are here given for various pressures on the soil from 1000 pounds to 10,000 pounds per square foot and having a bearing area ranging from 16 square feet to 196 square feet per footing. All footings are square, the smallest being 4 feet on a side and the largest 14 feet, the intermediate sizes being given for every six inches.

Concrete when restrained from lateral deformation can be given a longitudinal stress many times its natural resistance without lateral restraint. In a footing the reinforcement supplies this lateral restraint. That is the concrete at the top of a footing is continually under compression acting on lines running toward the column. This compression acts as a lateral restraint to the concrete directly under the base plate of the column. It can be readily seen that under the circumstance a tremendous unit pressure can be placed on this concrete without any damage whatever for there is no method by which failure can occur by crushing.

For this reason a unit pressure under base plates not exceeding 1500 pounds per square inch, has been considered in the tables as being permissable, and bearing plates in accordance with this pressure are called for in the footing tables and detailed on another page. Where building ordinances or inspectors will not permit the use of so high a pressure as is here advocated, the designer must of course, use larger sizes of such types as are satisfactory.

The thickness of the footing here given has been determined by shear in some cases and by bending moment in others.

It is a known fact that the resistance to real shear, (where the tension strains are eliminated) is about equal in concrete to its compressive resistance. Beams which fail by so called shear, really fail because of lack of resistance along the lines of diagonal tension. In a footing however, so far as the load on the base plate is concerned the real shearing strains, due to the punching of the base plate through the footing are actually developed, or at least failure by tension stresses is improbable. This is apparent for the reason that failure by tension takes place along lines at approximately 45 degrees slope. This slope or one even considerably greater would leave a truncated pyramid under the base plate so large, that the portion of the footing outside of the base of the pyramid, would not be sufficiently large to cause failure even by tension.

It has therefore been assumed in these tables that a footing of such thickness is required that the total load concentrated on the perimeter of the base plate, will not create a shear of more than 250 pounds per square inch on the concrete. This is certainly abundantly safe considering the fact that no allowance has been made for the resistance of the steel to shearing strains.

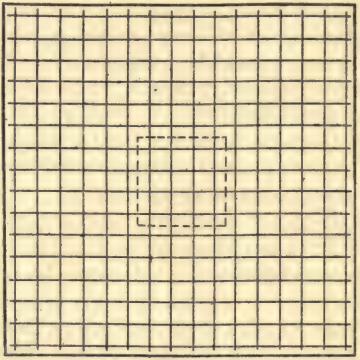
For resistance to bending, footings are provided of such thickness and with such reinforcement, that they have the proper resistance to bending along the line of the edge of the base plate, the same solution being used for the moment of resistance that has been already ex-

plained. In calculating the bending moment in footings it is assumed that the entire load per square foot is carried in each direction, the load not being divided by two for two-way reinforcement as in slabs.

The details of column footings show a half plan and two sectional elevations. These two sections which illustrate the type of reinforcement to be used are both correct and either may be used. The one with the battered top is given because in the larger footings considerable concrete may be eliminated without detracting from the strength of the footing. Although the total number of bars is the same in the battered footing, their arrangement and type is necessarily slightly different. There is some question as to the economy of the battered type however, in spite of the saving of concrete. The cost of forms to cover the footing so as to make the batter, the additional cost of placing the concrete through a hole in the center of the forms, the additional cost of labor on the reinforcement and the cost of back filling on top of the footing must all be considered. It is left to the designer to judge from local conditions which type to adopt.

Concrete for footings as in slabs, beams and columns is to be mixed in the proportions of one part of Portland cement to two and one-half parts of sand, to four parts of broken stone and enough water to make a pasty mixture.

PLAN AND SECTIONS
SHOWING REINFORCEMENT



PLAN

SECTION THROUGH FLAT FOOTING

SECTION THROUGH BATTERED FOOTING

FOOTINGS.

FOOTINGS 4′—0″ SQUARE

Pressure on the Soil per Square Foot	Total Carrying Capacity of Footing	Thickness of footing in Inches	Total Number of Rods in Footing	Diameter of Round Rods	Dimensions of Base Plate
1000	16000	12″	14	⅜″	12x12
2000	32000	12″	16	7/16″	12x12
3000	48000	12″	18	½″	12x12
4000	64000	12″	24	½″	12x12
5000	80000	14″	16	⅝″	12x12
6000	96000	14″	18	⅝″	12x12
8000	128000	16″	20	⅝″	12x12
10000	160000	18″	26	⅝″	12x12

FOOTINGS 4′—6″ SQUARE

Pressure on the Soil per Square Foot	Total Carrying Capacity of Footing	Thickness of footing in Inches	Total Number of Rods in Footing	Diameter of Round Rods	Dimensions of Base Plate
1000	20250	12″	14	⅜″	12x12
2000	40500	12″	20	7/16″	12x12
3000	60750	12″	22	½″	12x12
4000	81000	14″	24	½″	12x12
5000	101250	14″	20	⅝″	12x12
6000	127500	16″	22	⅝″	12x12
8000	162000	18″	24	⅝″	14x14
10000	202500	20″	26	⅝″	14x14

FOOTINGS 5′—0″ SQUARE

Pressure on the Soil per Square Foot	Total Carrying Capacity of Footing	Thickness of footing in Inches	Total Number of Rods in Footing	Diameter of Round Rods	Dimensions of Base Plate
1000	25000	12″	20	⅜″	12x12
2000	50000	12″	22	½″	12x12
3000	75000	14″	24	½″	12x12
4000	100000	14″	22	⅝″	12x12
5000	125000	16″	24	⅝″	12x12
6000	150000	16″	28	⅝″	12x12
8000	200000	18″	30	⅝″	14x14
10000	250000	20″	32	⅝″	16x16

FOOTINGS 5′—6″ SQUARE

Pressure on the Soil per Square Foot	Total Carrying Capacity of Footing	Thickness of footing in Inches	Total Number of Rods in Footing	Diameter of Round Rods	Dimensions of Base Plate
1000	30250	12″	20	7/16″	12x12
2000	60500	14″	24	1/2″	12x12
3000	90750	14″	22	5/8″	12x12
4000	121000	16″	26	5/8″	12x12
5000	151250	18″	30	5/8″	12x12
6000	181500	18″	34	5/8″	14x14
8000	242000	20″	38	5/8″	16x16
10000	302500	22″	44	5/8″	16x16

FOOTINGS 6′—0″ SQUARE

Pressure on the Soil per Square Foot	Total Carrying Capacity of Footing	Thickness of footing in Inches	Total Number of Rods in Footing	Diameter of Round Rods	Dimensions of Base Plate
1000	36000	14″	30	7/16″	12x12
2000	72000	14″	32	1/2″	12x12
3000	108000	16″	26	5/8″	12x12
4000	144000	16″	34	5/8″	12x12
5000	180000	18″	36	5/8″	14x14
6000	216000	20″	30	3/4″	16x16
8000	288000	22″	32	3/4″	16x16
10000	360000	24″	38	3/4″	18x18

FOOTINGS 6′—6″ SQUARE

Pressure on the Soil per Square Foot	Total Carrying Capacity of Footing	Thickness of footing in Inches	Total Number of Rods in Footing	Diameter of Round Rods	Dimensions of Base Plate
1000	42250	14″	30	7/16″	12x12
2000	84500	14″	42	1/2″	12x12
3000	126750	16″	36	5/8″	12x12
4000	169000	18″	40	5/8″	14x14
5000	211250	20″	42	5/8″	16x16
6000	253500	22″	32	3/4″	16x16
8000	338000	24″	42	3/4″	18x18
10000	422500	26″	48	3/4″	18x18

FOOTINGS 7′—0″ SQUARE

Pressure on the Soil per Square Foot	Total Carrying Capacity of Footing	Thickness of footing in Inches	Total Number of Rods in Footing	Diameter of Round Rods	Dimensions of Base Plate
1000	49000	14″	38	7/16″	12x12
2000	98000	16″	44	½″	12x12
3000	147000	18″	38	5/8″	14x14
4000	176000	20″	46	5/8″	14x14
5000	245000	22″	48	5/8″	16x16
6000	294000	24″	38	¾″	16x16
8000	352000	26″	48	¾″	18x18
10000	490000	28″	56	¾″	20x20

FOOTINGS 7′—6″ SQUARE

Pressure on the Soil per Square Foot	Total Carrying Capacity of Footing	Thickness of footing in Inches	Total Number of Rods in Footing	Diameter of Round Rods	Dimensions of Base Plate
1000	562500	14″	36	½″	14x14
2000	112500	16″	34	5/8″	14x14
3000	168750	18″	46	5/8″	14x14
4000	225000	20″	36	¾″	14x14
5000	281250	22″	40	¾″	16x16
6000	337500	24″	46	¾″	16x16
8000	450000	28″	38	7/8″	18x18
10000	562500	30″	46	7/8″	20x20

FOOTINGS 8′—0″ SQUARE

Pressure on the Soil per Square Foot	Total Carrying Capacity of Footing	Thickness of footing in Inches	Total Number of Rods in Footing	Diameter of Round Rods	Dimensions of Base Plate
1000	64000	16″	38	½″	14x14
2000	128000	18″	38	5/8″	14x14
3000	192000	20″	48	5/8″	14x14
4000	256000	22″	38	¾″	16x16
5000	320000	24″	46	¾″	16x16
6000	384000	28″	46	¾″	18x18
8000	512000	30″	42	7/8″	20x20
10000	640000	32″	48	7/8″	22x22

FOOTINGS 8′—6″ SQUARE

Pressure on the Soil per Square Foot	Total Carrying Capacity of Footing	Thickness of footing in Inches	Total Number of Rods in Footing	Diameter of Round Rods	Dimensions of Base Plate
1000	72250	16″	26	⅝″	14x14
2000	144500	18″	44	⅝″	14x14
3000	216750	20″	38	¾″	14x14
4000	289000	24″	44	¾″	16x16
5000	363250	26″	48	¾″	18x18
6000	433500	28″	42	⅞″	20x20
8000	578000	32″	46	⅞″	22x22
10000	722500	36″	52	⅞″	24x24

FOOTINGS 9′—0″ SQUARE

Pressure on the Soil per Square Foot	Total Carrying Capacity of Footing	Thickness of footing in Inches	Total Number of Rods in Footing	Diameter of Round Rods	Dimensions of Base Plate
1000	81000	16″	30	⅝″	14x14
2000	162000	20″	44	⅝″	14x14
3000	243000	22″	44	¾″	16x16
4000	324000	26″	46	¾″	18x18
5000	405000	30″	48	¾″	20x20
6000	486000	32″	54	¾″	22x22
8000	648000	34″	52	¾″	24x24
10000	810000	36″	62	⅞″	26x26

FOOTINGS 9′—6″ SQUARE

Pressure on the Soil per Square Foot	Total Carrying Capacity of Footing	Thickness of footing in Inches	Total Number of Rods in Footing	Diameter of Round Rods	Dimensions of Base Plate
1000	90250	16″	36	⅝″	16x16
2000	180500	18″	42	¾″	16x16
3000	270750	22″	48	¾″	18x18
4000	361000	26″	54	¾″	20x20
5000	451250	30″	42	⅝″	22x22
6000	541500	32″	48	⅞″	24x24
8000	721750	34″	62	⅞″	26x26
10000	902500	36″	70	⅞″	28x28

FOOTINGS 10′—0″ SQUARE

Pressure on the Soil per Square Foot	Total Carrying Capacity of Footing	Thickness of footing in Inches	Total Number of Rods in Footing	Diameter of Round Rods	Dimensions of Base Plate
1000	100000	18″	38	5/8″	16x16
2000	200000	20″	44	3/4″	16x16
3000	300000	24″	54	3/4″	18x18
4000	400000	28″	46	7/8″	20x20
5000	500000	32″	48	7/8″	22x22
6000	600000	34″	54	7/8″	24x24
8000	800000	36″	70	7/8″	26x26
10000	1000000	38″	80	7/8″	28x28

FOOTINGS 10′—6″ SQUARE

Pressure on the Soil per Square Foot	Total Carrying Capacity of Footing	Thickness of footing in Inches	Total Number of Rods in Footing	Diameter of Round Rods	Dimensions of Base Plate
1000	110250	18″	42	5/8″	18x18
2000	220500	20″	50	3/4″	18x18
3000	330750	24″	48	7/8″	18x18
4000	441000	28″	54	7/8″	18x18
5000	551250	32″	56	7/8″	20x20
6000	661500	34″	64	7/8″	24x24
8000	882000	36″	60	1″	26x26
10000	1102500	38″	72	1″	30x30

FOOTINGS 11′—0″ SQUARE

Pressure on the Soil per Square Foot	Total Carrying Capacity of Footing	Thickness of footing in Inches	Total Number of Rods in Footing	Diameter of Round Rods	Dimensions of Base Plate
1000	121000	18″	48	5/8″	18x18
2000	242000	20″	60	3/4″	18x18
3000	363000	24″	54	7/8″	18x18
4000	484000	28″	62	7/8″	20x20
5000	605000	32″	50	1″	22x22
6000	726000	34″	56	1″	24x24
8000	968000	38″	66	1″	26x26
10000	1210000	42″	76	1″	30x30

FOOTINGS 11′—6″ SQUARE

Pressure on the Soil per Square Foot	Total Carrying Capacity of Footing	Thickness of footing in Inches	Total Number of Rods in Footing	Diameter of Round Rods	Dimensions of Base Plate
1000	132250	18″	56	⅝″	18x18
2000	264500	22″	46	⅞″	18x18
3000	396750	26″	58	⅞″	20x20
4000	529000	30″	66	⅞″	20x20
5000	661250	34″	56	1″	22x22
6000	793500	38″	58	1″	24x24
8000	1058000	42″	70	1″	28x28
10000	1322500	46″	80	1″	32x32

FOOTINGS 12′—0″ SQUARE

Pressure on the Soil per Square Foot	Total Carrying Capacity of Footing	Thickness of footing in Inches	Total Number of Rods in Footing	Diameter of Round Rods	Dimensions of Base Plate
1000	144000	18″	44	½″	18x18
2000	288000	24″	48	⅞″	18x18
3000	432000	28″	62	⅞″	20x02
4000	576000	32″	68	⅞″	22x22
5000	720000	36″	58	1″	24x24
6000	864000	40″	64	1″	26x26
8000	1152000	44″	78	1″	30x30
10000	1440000	48″	82	1″	34x34

FOOTINGS 12′—6″ SQUARE

Pressure on the Soil per Square Foot	Total Carrying Capacity of Footing	Thickness of footing in Inches	Total Number of Rods in Footing	Diameter of Round Rods	Dimensions of Base Plate
1000	156250	20″	46	¾″	18x18
2000	312500	24″	58	⅞″	20x20
3000	468750	30″	64	⅞″	22x22
4000	625000	34″	76	⅞″	24x24
5000	781250	38″	64	1″	26x26
6000	937500	42″	66	1″	28x28
8000	1250000	46″	80	1″	32x32
10000	1562500	50″	92	1″	34x34

FOOTINGS 13′—0″ SQUARE

Pressure on the Soil per Square Foot	Total Carrying Capacity of Footing	Thickness of footing in Inches	Total Number of Rods in Footing	Diameter of Round Rods	Dimensions of Base Plate
1000	169000	20″	52	¾″	20x20
2000	338000	26″	60	⅞″	22x22
3000	507000	30″	74	⅞″	24x24
4000	676000	34″	66	1″	26x26
5000	845000	38″	74	1″	28x28
6000	1014000	42″	80	1″	30x30
8000	1352000	48″	88	1″	34x34
10000	1690000	52″	104	1″	36x36

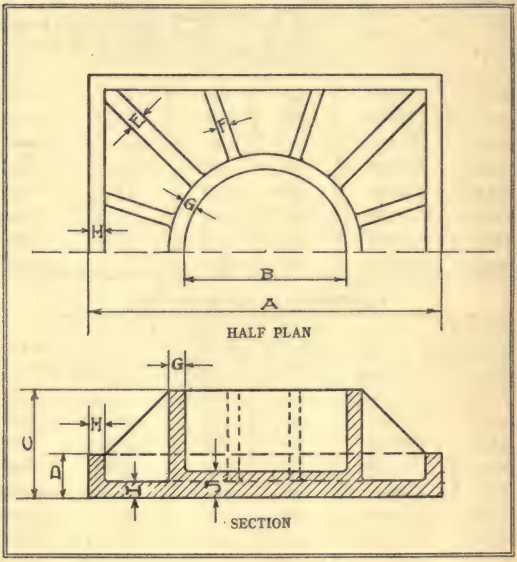
FOOTINGS 13′—6″ SQUARE

Pressure on the Soil per Square Foot	Total Carrying Capacity of Footing	Thickness of footing in Inches	Total Number of Rods in Footing	Diameter of Round Rods	Dimensions of Base Plate
1000	182250	20″	60	¾″	20x20
2000	364500	26″	66	⅞″	22x22
3000	546750	32″	76	⅞″	24x24
4000	729000	36″	68	1″	26x26
5000	911250	40″	76	1″	28x28
6000	1093500	44″	80	1″	30x30
8000	1458000	48″	96	1″	34x34
10000	1822500	52″	112	1″	38x38

FOOTINGS 14′—0″ SQUARE

Pressure on the Soil per Square Foot	Total Carrying Capacity of Footing	Thickness of footing in Inches	Total Number of Rods in Footing	Diameter of Round Rods	Dimensions of Base Plate
1000	196000	22″	62	¾″	20x20
2000	392000	26″	76	⅞″	22x22
3000	588000	32″	66	1″	24x24
4000	784000	36″	80	1″	26x26
5000	980000	42″	84	1″	28x28
6000	1176000	46″	90	1″	30x30
8000	1568000	50″	110	1″	34x34
10000	1960000	54″	130	1″	38x38

CAST IRON BASE PLATES.



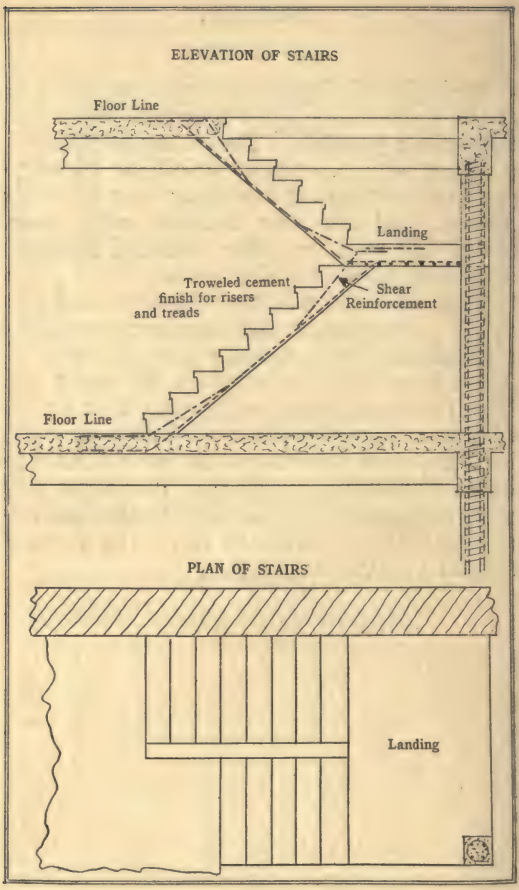
BASE PLATE DIMENSIONS

A	B	C	D	E	F	G	H	I	J
20″	9″	5″	2¼″	1¼″	1″	1″	1″	1″	2″
22″	11″	5½″	2½″	1¼″	1″	1″	1″	1″	2″
24″	13″	6″	2¾″	1½″	1″	1¼″	1″	1″	2″
26″	13″	6½″	3″	1½″	1¼″	1¼″	1¼″	1¼″	2¼″
28″	15″	7″	3¼″	1¾″	1¼″	1½″	1¼″	1¼″	2½″
30″	15″	7½″	3½″	1¾″	1¼″	1½″	1½″	1¼″	2¾″
32″	17″	8″	3½″	2″	1½″	1¾″	1½″	1½″	3″
34″	17″	8½″	3¾″	2″	1½″	1¾″	1½″	1½″	3¼″
36″	19″	9″	4″	2¼″	1½″	2″	1¾″	1½″	3¼″
38″	19″	9½″	4¼″	2¼″	1½″	2″	1¾″	1½″	3½″

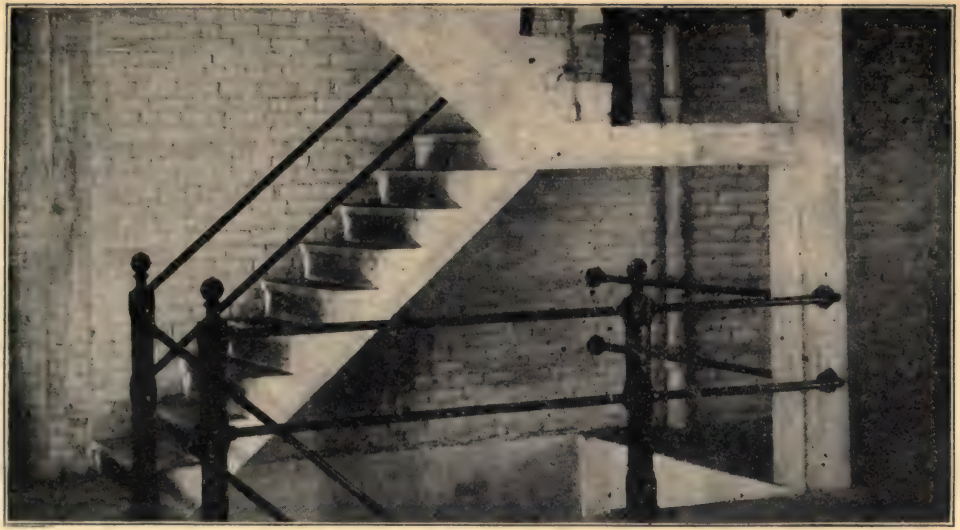
STAIRS.

Stairs in reinforced concrete are economical and the most thoroughly fireproof type of stair construction possible. They may be finished on top either with a cement finish, or merely the structural portions of the stair may be built in concrete, and the top finished with marble, mosaic, cast iron, or other material suitable to the architectural requirements.

The type of stairs here detailed and photographed is that where stringers are not used but the treads are built directly upon a slab. This method is entirely satisfactory for short spans. Where the span becomes so great that the dead load of the stairs plus the live load requires a very thick slab, a stringer should be built at each side, the treads spanning between and acting as beams. The stringers are calculated the same as beams, the details being suited to resist the shear produced at the various angles.


ELEVATION OF STAIRS
Floor Line
Landing
Troweled cement
finish for risers
and treads
Shear
Reinforcement
Floor Line
PLAN OF STAIRS
Landing

STAIRS.



THE SAME STAIR ERECTED.

CONSTRUCTION OF FORMS.

On the following pages is given a method of building forms which are entirely collapsible, and which have been used extensively in the construction of buildings. This method of construction has proved extremely satisfactory because of its economy. The use of the 2″ solid plank may seem superfluous but in the end it is the cheapest way, because the 2″ plank will hold its position without being nailed, where a $\frac{7}{8}$″ board would warp or would be broken by the handling of the material on top of it. Furthermore, heavy forms will have more salvage in them than light ones, coming out almost without damage. Forms should be figured to be used from two to four times, depending upon the size of the building.

In warm climates or where conditions are favorable for setting rapidly, forms for two complete floors should be sufficient for a building taking about ten days to a floor. The estimator should however consider that in using forms three times, about fifty per cent additional lumber will have to be supplied to make up for that damaged in changing from floor to floor.

As was mentioned in the general principles of design given in the front part of the book, the expense of forms may be largely influenced by the designer by his selection of beam and column size for the various portions of the structure.

It ought to be unnecessary to caution the contractor in regard to taking down forms too soon, but there have been so many collapses due to carelessness on this point, that a word of warning seems wise.

The setting time of concrete is very largely influenced by weather conditions. A hot dry atmosphere will cause it to set much more rapidly than cold air heavily laden with moisture. A building of the skeleton type open to the circulation of air will become self supporting in less time than one tightly enclosed within walls.

The time which has elapsed after placing the concrete should not be the only consideration in taking down forms. The concrete should be throughly examined by one experienced to see that it has the proper set. A few of the planks should be removed to test the slabs on the under side. A good practice in removing forms is to remove those from under the slab, leaving the beam and column forms entirely in place. The slab when exposed to the air on the under side will harden much more rapidly, and being well bonded to the beam will materially strengthen it, although the latter may not have attained its ultimate strength.

If there is the slightest doubt about the strength of the beams, a support should be placed under the center of each as soon as the forms are removed, and left there until there is no question about the strength of the beam.

In the system of forming shown, the joists are supported upon the beams by means of a loose piece of 4x4, which may be removed, thus removing, the entire support of the joists, so they may be immediately taken down, together with the 2″ plank used for the slab. After the removal of the joists and the slab, the forms for the beams are removed by opening them away from the beam, the sides swinging on the bolts which act as hinges at the lower ends of the battens.

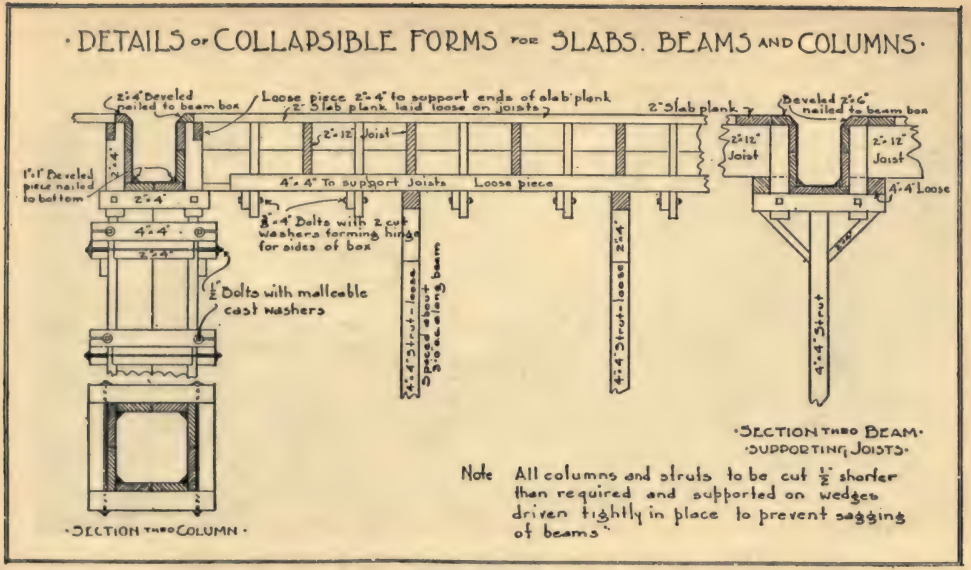
Column forms are built entirely of 2″ stuff having each side held together by battens. Binders for the column forms consist of 4x4 pine slotted at the ends to receive ½″ bolts having malleable cast washers. It will be noticed that the beam supporting the joists is slightly different from the beam parallel to the joists.

For estimating purposes it may be considered that the forms as shown will require about 3 feet board measure for the slabs alone, which includes the slab plank and joists. For the beam supporting the joists and including the 4x4 struts about 21 feet B. M. per lineal foot of beam will be required for a beam 10″x15″ below the slab, 24 ft. B. M. for a beam 12″x21″ and 27 feet B. M. for one 14″x27″. Other beams will require lumber in proportion. For the beams parallel to joists the lumber required is about 2 feet B. M. less per lineal foot than called for above. Column forms including binders and battens will require 15 B. M. for a 12″x12″ column, 21 B. M. for a 16″ column, 27 B. M. for a 20″ column and 33 B. M. for a 24″ column.

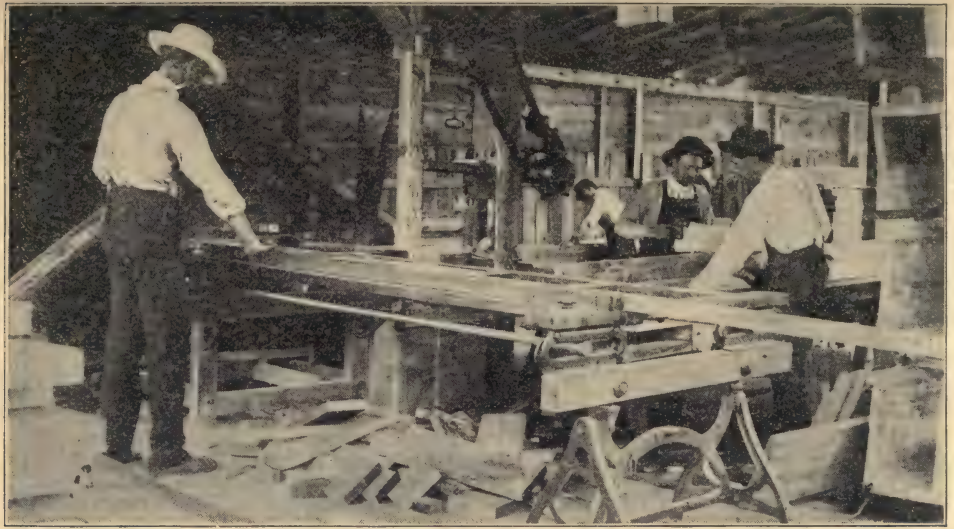
The method of manufacture and erection of these forms is apparent from the photographs here reproduced.

The contractor can well afford to equip with portable saw mills, boring machines, etc., under cover, and all arranged so that the column forms and beam boxes can be made from details, ready to erect.

Such an equipment is here illustrated. Column and beam forms are also shown in the process of erection and a view from the under side shows very clearly the complete construction of forms in place.

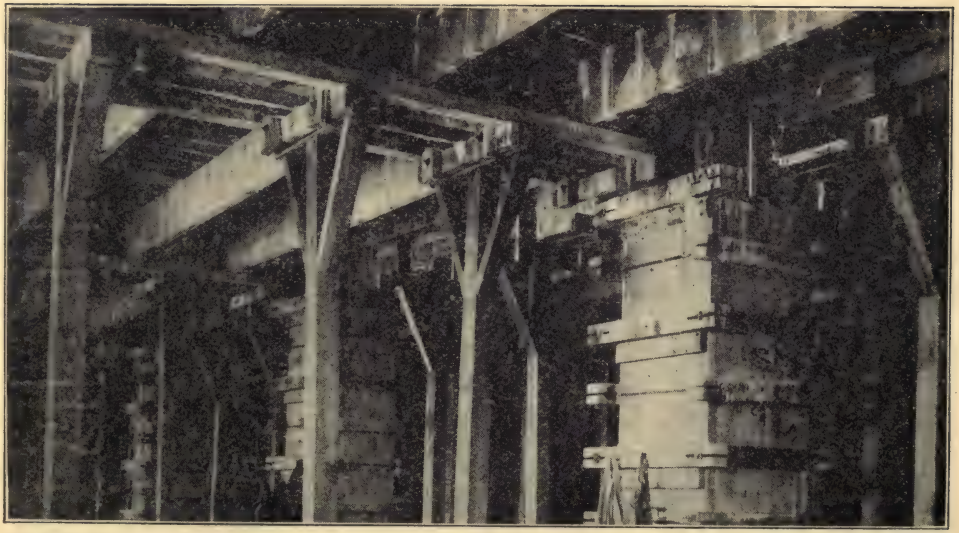

DETAILS OF COLLAPSIBLE FORMS FOR SLABS. BEAMS AND COLUMNS
2"-4" Beveled nailed to beam box
Loose piece 2"-4" to support ends of slab plank
2"-Slab plank laid loose on joists
2"-Slab plank
Beveled 2"-6" nailed to beam box
2"-12" Joist
2"-12" Joist
2"-12" Joist
1"-1" Beveled piece nailed to bottom
4"-4" To support Joists
Loose piece
4"-4" Loose
2"-4"
4"-4"
2"-4"
⅝" Bolts with 2 cut washers forming hinge for sides of box
⅝" Bolts with malleable cast washers
4"-4" Strut - loose
Spaced about 5 to a long beam
4"-4" Strut - loose
2"-4"
4"-4" Strut
SECTION THRO COLUMN
SECTION THRO BEAM SUPPORTING JOISTS
Note All columns and struts to be cut ½" shorter than required and supported on wedges driven tightly in place to prevent sagging of beams.

FORM DETAILS.



THE MILL FOR THE MANUFACTURE OF FORMS.

ERECTING BEAM FORMS.



FORMS IN PLACE.

PROPORTIONS OF MATERIALS IN CONCRETE.

The tables here given are taken from experiments made at the University of Cornell, and it has been found by experience that the proportions of the various materials required to make one cubic yard of concrete agree fairly well with the quantities given in these tables. They are not given as being absolutely correct, but as the best available information on the subject and entirely satisfactory for estimating purposes. For use in reinforced concrete the table for gravel and the one with the hazelnut stone should be used. Stone of 2″ size is rarely used in reinforced concrete work, because it is liable to clog up the reinforcement and leave many unfilled spaces.

It seems to be common practice to specify concrete of the proportions of one part of cement to two parts of sand to four parts of broken stone or gravel. This proportion may be correct in theory but in practice, it has been found that there ought to be a little more mortar than rock, in order to easily fill the voids and prevent porous concrete. It is recommended here to increase the sand to two and one-half parts, which will give a concrete of ample strength and one in which all voids will be easily filled. Water should be used in such quantities as to make a pasty mixture, but it should not be used so freely as to drain out through the cracks in the forms washing the cement and sand with it and leaving the concrete full of holes.

GRAVEL CONCRETE.

AMOUNTS OF CEMENT, SAND AND STONE REQUIRED FOR CONCRETE MIXTURES.

Concrete with Gravel ¾″ and Under.

Proportions			Required for 1 Cubic Yard.		
Cement	Sand	Gravel	Cement Bbls.	Sand Cu. Yds.	Gravel Cu. Yds.
1	1.0	2.5	2.10	0.32	0.80
1	1.0	3.0	1.89	0.29	0.86
1	1.0	3.5	1.71	0.26	0.91
1	1.0	4.0	1.55	0.24	0.94
1	1.5	3.0	1.71	0.39	0.78
1	1.5	3.5	1.57	0.36	0.83
1	1.5	4.0	1.46	0.33	0.88
1	1.5	4.5	1.34	0.31	0.91
1	1.5	5.0	1.24	0.28	0.94
1	2.0	3.5	1.44	0.44	0.77
1	2.0	4.0	1.34	0.41	0.81
1	2.0	4.5	1.26	0.38	0.86
1	2.0	5.0	1.17	0.36	0.89
1	2.0	6.0	1.03	0.31	0.94
1	2.5	4.0	1.24	0.47	0.75
1	2.5	4.5	1.16	0.44	0.80
1	2.5	5.0	1.10	0.42	0.83
1	2.5	5.5	1.03	0.39	0.86
1	2.5	6.0	0.98	0.37	0.89
1	2.5	7.0	0.88	0.33	0.93
1	3.0	5.0	1.03	0.47	0.78
1	3.0	5.5	0.97	0.44	0.81
1	3.0	6.0	0.92	0.42	0.84
1	3.0	6.5	0.88	0.40	0.87
1	3.0	7.0	0.84	0.38	0.89
1	3.0	7.5	0.80	0.37	0.91
1	3.0	8.0	0.76	0.35	0.93
1	3.5	6.0	0.88	0.46	0.80
1	3.5	6.5	0.83	0.44	0.82
1	3.5	7.0	0.80	0.43	0.85
1	3.5	7.5	0.76	0.41	0.87
1	3.5	8.0	0.73	0.39	0.89
1	3.5	8.5	0.71	0.38	0.91
1	3.5	9.0	0.68	0.36	0.92
1	4.0	7.0	0.77	0.47	0.81
1	4.0	7.5	0.73	0.44	0.83
1	4.0	8.0	0.71	0.43	0.86
1	4.0	8.5	0.68	0.42	0.88
1	4.0	9.0	0.65	0.40	0.89
1	4.0	9.5	0.63	0.38	0.91
1	4.0	10.0	0.61	0.37	0.93
1	5.0	10.0	0.57	0.43	0.87
1	5.0	12.0	0.51	0.38	0.92
1	6.0	12.0	0.48	0.44	0.88
1	6.0	14.0	0.43	0.40	0.92
1	7.0	14.0	0.42	0.44	0.88
1	7.0	16.0	0.38	0.40	0.92

HAZELNUT STONE CONCRETE.

AMOUNTS OF CEMENT, SAND AND STONE REQUIRED FOR CONCRETE MIXTURES.

Concrete with "Hazelnut" Stone.

Proportions			Required for 1 Cubic Yard.		
Cement	Sand	Stone	Cement Bbls.	Sand Cu. Yds.	Stone Cu. Yds.
1	1.0	2.0	2.57	0.39	0.78
1	1.0	2.5	2.29	0.35	0.86
1	1.0	3.0	2.06	0.31	0.94
1	1.0	3.5	1.84	0.28	0.98
1	1.5	2.5	2.05	0.47	0.78
1	1.5	3.0	1.85	0.42	0.84
1	1.5	3.5	1.72	0.39	0.91
1	1.5	4.0	1.57	0.36	0.96
1	1.5	4.5	1.43	0.33	0.98
1	2.0	3.0	1.70	0.52	0.77
1	2.0	3.5	1.57	0.48	0.83
1	2.0	4.0	1.46	1.44	0.89
1	2.0	4.5	1.36	0.42	0.93
1	2.0	5.0	1.27	0.39	0.97
1	2.5	3.5	1.45	0.55	0.77
1	2.5	4.0	1.35	0.52	0.82
1	2.5	4.5	1.27	0.48	0.87
1	2.5	5.0	1.19	0.46	0.91
1	2.5	5.5	1.13	0.43	0.94
1	2.5	6.0	1.07	0.41	0.97
1	3.0	4.0	1.26	0.58	0.77
1	3.0	4.5	1.18	0.54	0.81
1	3.0	5.0	1.11	0.51	0.85
1	3.0	5.5	1.06	0.48	0.89
1	3.0	6.0	1.01	0.46	0.92
1	3.0	6.5	0.96	0.44	0.95
1	3.0	7.0	0.91	0.42	0.97
1	3.5	5.0	1.05	0.56	0.80
1	3.5	5.5	1.00	0.53	0.84
1	3.5	6.0	0.95	0.50	0.87
1	3.5	6.5	0.92	0.49	0.91
1	3.5	7.0	0.87	0.47	0.93
1	3.5	7.5	0.84	0.45	0.96
1	3.5	8.0	0.80	0.42	0.97
1	4.0	6.0	0.90	0.55	0.82
1	4.0	6.5	0.87	0.53	0.85
1	4.0	7.0	0.83	0.51	0.89
1	4.0	7.5	0.80	0.49	0.91
1	4.0	8.0	0.77	0.47	0.93
1	4.0	8.5	0.74	0.45	0.95
1	4.0	9.0	0.71	0.43	0.97
1	5.0	9.0	0.66	0.50	0.90
1	5.0	10.0	0.62	0.47	0.95
1	6.0	11.0	0.55	0.51	0.93
1	6.0	12.0	0.52	0.48	0.95
1	7.0	13.0	0.47	0.50	0.93
1	7.0	14.0	0.45	0.48	0.96

GRADED STONE CONCRETE.

AMOUNTS OF CEMENT, SAND AND STONE REQUIRED FOR CONCRETE MIXTURES.

Concrete with Stone 2½" and Under

Proportions			Required for 1 Cubic Yard.		
Cement	Sand	Gravel	Cement Bbls.	Sand Cu. Yds.	Stone Cu. Yds.
1	1.0	2.0	2.63	0.40	0.80
1	1.0	2.5	2.34	0.36	0.89
1	1.0	3.0	2.10	0.32	0.96
1	1.0	3.5	1.88	0.29	1.00
1	1.5	2.5	2.09	0.48	0.80
1	1.5	3.0	1.90	0.43	0.87
1	1.5	3.5	1.74	0.40	0.93
1	1.5	4.0	1.61	0.37	0.98
1	1.5	4.5	1.46	0.33	1.00
1	2.0	3.0	1.73	0.53	0.79
1	2.0	3.5	1.61	0.49	0.85
1	2.0	4.0	1.48	0.45	0.90
1	2.0	4.5	1.38	0.42	0.95
1	2.0	5.0	1.29	0.39	0.98
1	2.5	3.5	1.48	0.56	0.79
1	2.5	4.0	1.38	0.53	0.84
1	2.5	4.5	1.29	0.49	0.88
1	2.5	5.0	1.21	0.46	0.92
1	2.5	5.5	1.15	0.44	0.96
1	2.5	6.0	1.07	0.41	0.98
1	3.0	4.0	1.28	0.58	0.78
1	3.0	4.5	1.20	0.55	0.82
1	3.0	5.0	1.14	0.52	0.87
1	3.0	5.5	1.07	0.49	0.90
1	3.0	6.0	1.02	0.47	0.93
1	3.0	6.5	0.98	0.44	0.96
1	3.0	7.0	0.92	0.42	0.98
1	3.5	5.0	1.07	0.57	0.82
1	3.5	5.5	1.02	0.54	0.85
1	3.5	6.0	0.97	0.51	0.89
1	3.5	6.5	0.93	0.49	0.92
1	3.5	7.0	0.89	0.47	0.95
1	3.5	7.5	0.86	0.45	0.98
1	4.0	6.0	0.92	0.56	0.84
1	4.0	6.5	0.88	0.53	0.87
1	4.0	7.0	0.84	0.51	0.90
1	4.0	7.5	0.81	0.50	0.93
1	4.0	8.0	0.78	0.48	0.95
1	4.0	8.5	0.76	0.46	0.98
1	5.0	9.0	0.67	0.52	0.93
1	5.0	10.0	0.63	0.48	0.96
1	6.0	11.0	0.56	0.52	0.94
1	6.0	12.0	0.54	0.49	0.98
1	7.0	13.0	0.48	0.51	0.95
1	7.0	14.0	0.46	0.49	0.98

TWO AND ONE-HALF INCH STONE CONCRETE.

AMOUNTS OF CEMENT, SAND AND STONE REQUIRED FOR CONCRETE MIXTURES.

Concrete with Stone 2½″

Proportions			Required for 1 Cubic Yard.		
Cement	Sand	Stone	Cement Bbls.	Sand Cu. Yds.	Stone Cu. Yds.
1	1.0	2.0	2.72	0.41	0.83
1	1.0	2.5	2.41	0.37	0.92
1	1.0	3.0	2.16	0.33	0.98
1	1.5	2.5	2.16	0.49	0.82
1	1.5	3.0	1.96	0.45	0.89
1	1.5	3.5	1.79	0.41	0.96
1	1.5	4.0	1.64	0.38	1.00
1	2.0	3.0	1.78	0.54	0.81
1	2.0	3.5	1.66	0.50	0.88
1	2.0	4.0	1.53	0.47	0.93
1	2.0	4.5	1.43	0.43	0.98
1	2.5	3.5	1.51	0.58	0.81
1	2.5	4.0	1.42	0.54	0.87
1	2.5	4.5	1.33	0.51	0.91
1	2.5	5.0	1.26	0.48	0.96
1	2.5	5.5	1.18	0.44	0.99
1	3.0	4.0	1.32	0.60	0.80
1	3.0	4.5	1.24	0.57	0.85
1	3.0	5.0	1.17	0.54	0.89
1	3.0	5.5	1.11	0.51	0.93
1	3.0	6.0	1.06	0.48	0.97
1	3.5	5.0	1.11	0.59	0.85
1	3.5	5.5	1.06	0.56	0.89
1	3.5	6.0	1.00	0.53	0.92
1	3.5	6.5	0.96	0.51	0.95
1	3.5	7.0	0.91	0.49	0.98
1	4.0	6.0	0.95	0.58	0.87
1	4.0	6.5	0.91	0.55	0.90
1	4.0	7.0	0.87	0.53	0.93
1	4.0	7.5	0.84	0.51	0.96
1	4.0	8.0	0.81	0.49	0.98
1	5.0	8.0	0.74	0.57	0.91
1	5.0	9.0	0.70	0.53	0.96
1	6.0	9.0	0.65	0.59	0.89
1	6.0	10.0	0.62	0.56	0.93
1	7.0	11.0	0.54	0.51	0.91
1	7.0	12.0	0.52	0.55	0.95

WHAT BARS TO USE.

Considerable is left to the judgement of the designer as to the proper bars to select after the tensile strength required, has been determined.

Some engineers claim considerable advantage for high carbon bars because of the high elastic limit. One objection to the practice is that a high elastic limit encourages a high working stress in the steel, and the specification which allows a working load "not higher than one-half, or even one-third, of the elastic limit" is very likely to be abused by permitting the use of a steel of too high a carbon. Another objection to high carbon bars is that unless some standard is adopted, their manufacture will consist of a special rolling for each order, which results in confusion, delay and probable noncompliance with the specification in many cases, besides rendering the buying of bars from stock impossible.

These standards are based on the use of medium steel which may be used at a working load of 16000 pounds per square inch, for the reason that this is a standard quality with all mills, and is carried by all jobbers in stock, and besides even if for technical reasons high carbon steel is used, it is here considered, that it should be used as a means of increasing the factor of safety rather than the working load.

Another very important point for the designer to consider is the diameters of bars selected. Sixteenth sizes above one-half inch in diameter are bad from a commercial point of

view, because they are not as commonly carried in stock as are other bars, any way the design can be so arranged as not to require them. The designer for ease of erection should avoid variety in diameters and lengths, and should especially avoid bars of *nearly* the same diameter.

At another point the question of adhesion is discussed. The designer should see that in all cases the bars selected are of small enough diameter that the length imbedded is sufficient to develop the strength of the bar.

Tables are given on the following pages for the weights and areas of square and round bars, for the cross sectional area of round bars per foot of width for various spacings and for the tension in round bars under the same conditions.

These tables will be found useful to the designer.

WEIGHTS AND AREAS OF SQUARE AND ROUND BARS

Thickness or Diameter in in.	Weight of Square Bar One Ft. Long	Weight of Round Bar One Ft. Long	Area of Square Bar in Sq. Inches	Area of Round Bar in Sq. Inches
0				
1/16	.013	.010	.0039	.0031
1/8	.053	.042	.0156	.0123
3/16	.119	.094	.0352	.0276
1/4	.212	.167	.0625	.0491
5/16	.333	.261	.0977	.0767
3/8	.478	.375	.1406	.1104
7/16	.651	.511	.1914	.1503
1/2	.850	.667	.2500	.1963
9/16	1.076	.845	.3164	.2485
5/8	1.328	1.043	.3906	.3068
11/16	1.608	1.262	.4727	.3712
3/4	1.913	1.502	.5625	.4418
13/16	2.245	1.763	.6602	.5185
7/8	2.603	2.044	.7656	.6013
15/16	2.989	2.347	.8789	.6903
1	3.400	2.670	1.0000	.7854
1/16	3.838	3.014	1.1289	.8866
1/8	4.303	3.379	1.2656	.9940
3/16	4.795	3.766	1.4102	1.1075
1/4	5.312	4.173	1.5625	1.2272
5/16	5.857	4.600	1.7227	1.3530
3/8	6.428	5.049	1.8906	1.4849
7/16	7.026	5.518	2.0664	1.6230
1/2	7.650	6.008	2.2500	1.7671
9/16	8.301	6.520	2.4414	1.9175
5/8	8.978	7.051	2.6406	2.0739
11/16	9.682	7.604	2.8477	2.2365
3/4	10.41	8.178	3.0625	2.4053
13/16	11.17	8.773	3.2852	2.5802
7/8	11.95	9.388	3.5156	2.7612
15/16	12.76	10.02	3.7539	2.9483

WEIGHTS AND AREAS OF SQUARE AND ROUND BARS

Thickness or Diameter in in.	Weight of Square Bar One Ft. Long	Weight of Round Bar One Ft. Long	Area of Square Bar in Sq. Inches	Area of Round Bar in Sq. Inches
2	13.60	10.68	4.0000	3.1416
1/16	14.46	11.36	4.2539	3.3410
1/8	15.35	12.06	4.5156	3.5466
3/16	16.27	12.78	4.7852	3.7583
1/4	17.22	13.52	5.0625	3.9761
5/16	18.19	14.28	5.3477	4.2000
3/8	19.18	15.07	5.6406	4.4301
7/16	20.20	15.86	5.9414	4.6664
1/2	21.25	16.69	6.2500	4.9087
9/16	22.33	17.53	6.5664	5.1572
5/8	23.43	18.40	6.8906	5.4119
11/16	24.56	19.29	7.2227	5.6727
3/4	25.71	20.20	7.5625	5.9396
13/16	26.90	21.12	7.9102	6.2126
7/8	28.10	22.07	8.2656	6.4918
15/16	29.34	23.04	8.6289	6.7771
3	30.60	24.03	9.0000	7.0686
1/16	31.89	25.04	9.3789	7.3662
1/8	33.20	26.08	9.7656	7.6699
3/16	34.55	27.13	10.160	7.9798
1/4	35.92	28.20	10.563	8.2958
5/16	37.31	29.30	10.973	8.6179
3/8	38.73	30.42	11.391	8.9462
7/16	40.18	31.56	11.816	9.2806
1/2	41.65	32.71	12.250	9.6211
9/16	43.14	33.90	12.691	9.9678
5/8	44.68	35.09	13.141	10.321
11/16	46.24	36.31	13.598	10.680
3/4	47.82	37.56	14.063	11.045
13/16	49.42	38.81	14.535	11.416
7/8	51.05	40.10	15.016	11.793
15/16	52.71	41.40	15.504	12.177

TENSION IN ROUND RODS

Per Foot of Width

For Diameters and Spacing given.

16000 Lbs. Per Square Inch Fibre Strain.

Spacing of Rods in Inches.	Diameter of Rods ¼″	5/16″	3/8″	7/16″	½″
3	3140	4909	7065	9619	12563
3½	2693	4206	6054	8243	10766
4	2357	3680	5299	7214	9422
4½	2094	3272	4710	6413	8374
5	1885	2944	4238	5771	7538
5½	1712	2675	3850	5241	6846
6	1570	2454	3533	4810	6282
6½	1450	2264	3259	4438	5797
7	1346	2103	3027	4122	5383
7½	1257	1963	2826	3846	5024
8	1178	1840	2650	3607	4711
9	1047	1636	2355	3206	4187
10	942	1472	2119	2885	3769
11	856	1337	1925	2620	3423
12	785	1227	1766	2405	3141
13	725	1132	1629	2219	2898
14	673	1051	1513	2061	2691
15	628	981	1413	1923	2512

TENSION IN ROUND RODS

Per Foot of Width

For Diameters and Spacing given.

16000 Lbs. Per Square Inch Fibre Strain.

SPACING OF RODS IN INCHES.	Diamtr. of Rod	9/16″	5/8″	11/16″	3/4″	7/8″	1″
	3 ″	15904	19635	23756	28275	38483	50266
	3½″	13629	16827	20358	24232	32979	43077
	4 ″	11928	14726	17817	21206	28862	37699
	4½″	10602	13089	15838	18990	25656	33510
	5 ″	9542	11780	14253	16965	23090	30158
	5½″	8667	10701	12947	15410	20973	27393
	6 ″	7952	9818	11878	14138	19242	25133
	6½″	7339	9061	10963	13048	17758	23197
	7 ″	6814	8413	10179	12116	16490	21538
	7½″	6362	7853	9502	11309	15392	20106
	8 ″	5964	7363	8909	10603	14430	18850
	9 ″	5301	6544	7919	9495	12828	16755
	10″	4771	5890	7126	8482	11545	15079
	11″	4333	5350	6473	7705	10486	13696
	12″	3976	4909	5939	7069	9621	12566
	13″	3669	4530	5481	6524	8879	11598
	14″	3407	4206	5089	6058	8245	10769
	15″	3181	3926	4751	5654	7696	10053

AREA OF ROUND RODS

In Square Inches Per Foot of Width For Diameters and Spacing Given.

Spacing of Rods in Inches	Diameter of Rod ¼″	5/16″	⅜″	7/16″	½″	9/16″	⅝″	11/16″	¾″	⅞″	1″
3″	.196	.307	.441	.601	.785	.994	1.227	1.485	1.767	2.405	3.141
3½″	.168	.263	.378	.515	.673	.852	1.052	1.272	1.514	2.061	2.692
4″	.147	.230	.331	.451	.589	.745	.920	1.113	1.325	1.804	2.356
4½″	.131	.204	.294	.401	.523	.663	.818	.990	1.178	1.603	2.094
5″	.118	.184	.265	.361	.471	.596	.736	.891	1.060	1.443	1.885
5½″	.107	.167	.240	.327	.428	.542	.669	.809	.963	1.311	1.712
6″	.098	.153	.221	.300	.392	.497	.613	.742	.883	1.202	1.571
6½″	.090	.141	.204	.277	.362	.458	.566	.685	.815	1.110	1.450
7″	.084	.131	.189	.257	.336	.426	.526	.636	.757	1.030	1.346
7½″	.078	.123	.176	.240	.314	.397	.491	.594	.707	.962	1.256
8″	.073	.115	.165	.225	.294	.373	.460	.557	.663	.902	1.178
9″	.066	.102	.146	.200	.262	.330	.405	.495	.590	.800	1.05
10″	.058	.091	.132	.180	.235	.297	.365	.445	.530	.720	.940
11″	.053	.083	.120	.163	.214	.271	.314	.404	.481	.655	.856
12″	.049	.076	.110	.150	.196	.248	.306	.371	.442	.601	.785
13″	.045	.070	.102	.138	.181	.229	.283	.342	.407	.555	.725
14″	.042	.065	.094	.128	.167	.212	.263	.318	.376	.515	.665
15″	.039	.061	.088	.120	.157	.198	.245	.297	.353	.481	.628

ADHESION OF CONCRETE TO RODS.

Tests show that plain rods imbedded in concrete will develop an ultimate adhesion of something over 200 pounds per square inch. It is considered in good practice that 50 pounds per square inch is safe. In case the rods should be imbedded with a hook on the end or in a curved form, because of the increased friction, far more than 50 pounds to the square inch would be developed. In the case of heavy rods imbedded as tension members, care should be taken that a sufficient length of bar is imbedded in the concrete to develop the strength of the rod itself at the strain for which it is calculated.

The table given indicates the length of round rods of various diameters imbedded in concrete, so that when the adhesion equals 50 pounds per square inch of surface, the strength of the rod will be fully developed, the fibre strain being calculated at 16,000 pounds, per square inch.

ADHESION OF CONCRETE TO RODS

Required length of straight rods imbedded to develop fiber strain of 16000 pounds per square inch, adhesion of 50 pounds per square inch of surface.

Diameter	Length Imbedded	Diameter	Length Imbedded	Diameter	Length Imbedded
$\frac{1}{4}$	1′-8″	$\frac{5}{8}$	4- 2″	$1\frac{3}{8}$″	9- 2″
$\frac{5}{16}$	2′-1″	$\frac{3}{4}$	5- 0″	$1\frac{1}{2}$″	10- 0″
$\frac{3}{8}$	2′-6″	$\frac{7}{8}$	5-10″	$1\frac{5}{8}$″	10-10″
$\frac{7}{16}$	2′-11″	1 ″	6- 8″	$1\frac{3}{4}$″	10- 8″
$\frac{1}{2}$	3′-4″	$1\frac{1}{8}$″	7- 6″	$1\frac{7}{8}$″	12- 6″
$\frac{9}{16}$	3′-9″	$1\frac{1}{4}$″	8- 5″	2″	13- 4″

SHOP DETAILS.

The following pages illustrate the "types" of rods used in "The Uniform Design" and show how, by combination of these "types," all ordinary slabs and beams are reinforced.

If detailers will make it a practice to use the notation here given for the various forms of rods, it will be of great assistance to workmen and to others familiar with standard construction.

In preparing rods for the structure they should be tied in bundles of convenient size to handle with the apparatus at hand. Each bundle should contain only beams of one "type" and should be properly labeled for identification. For convenience in erection the number of rods in one bundle should be for one floor only, for no broken bundles should await erection.

Bending of rods can almost always be done cold and it will be found far more economical than blacksmith work.

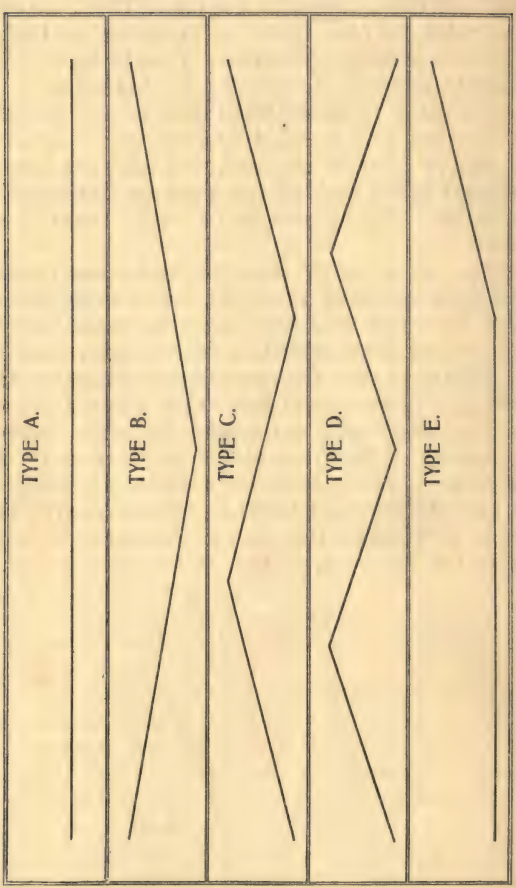
The first requirement for detailing is a framing plan showing the exact location of all columns and beams by means of figured dimensions. Beams should *always* be represented by means of a *center line*, and not by two lines, and dimensions should be to this center line.

The primary object in a framing plan is to locate the various beams by their "marks." Each beam should receive a number, similiar beams being marked with similiar numbers.

In detailing, the "mark" is given for each beam and the number of beams of this "mark" is indicated for each floor, or for the entire building as the designer desires. This is most conveniently done by the use of a rubber stamp. A second stamp properly filled out should indicate the "types" and number of rods, and diameter and length of each required to make *one* beam. The total bill of rods giving sizes and lengths for the entire building should be made from these details.

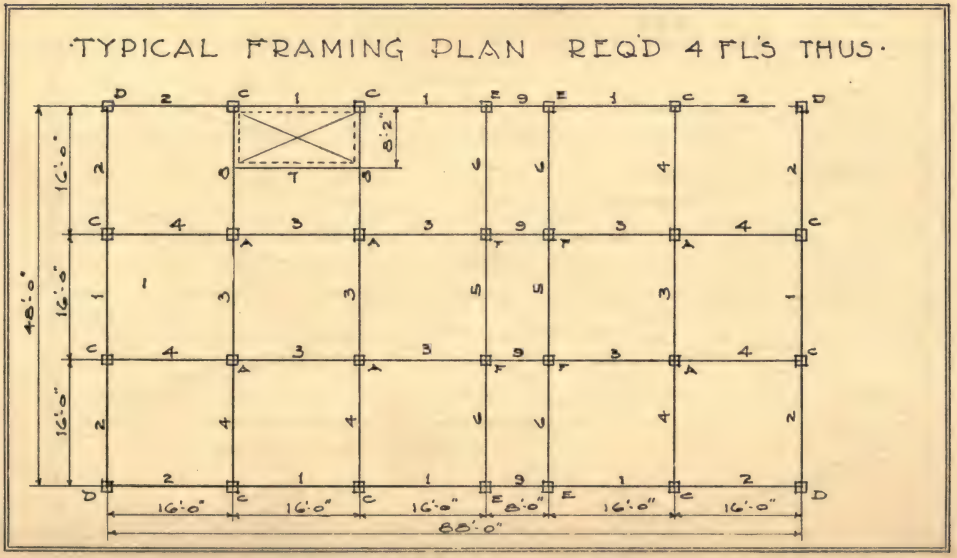
For economy of manufacture shop details should always be of all regular beam and column forms, in order that they may be made at the shop and sent to the building for erection only.

Where beams are exceedingly irregular and especially in the case of stair ways where the construction may not agree exactly with figured dimensions, it is advisable to indicate only the general style of construction, sufficiently to show the material ordered for the purpose leaving the details of construction to the foreman to work out on the job.

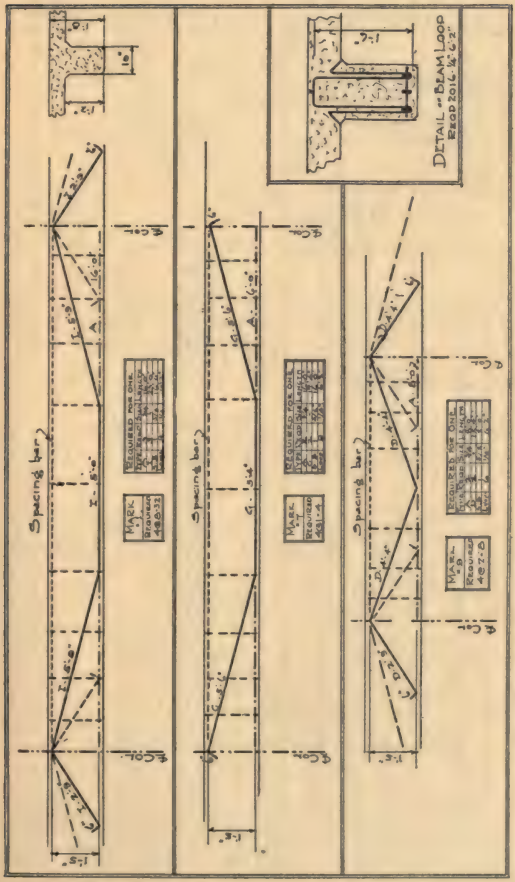


STANDARD TYPES OF BARS.

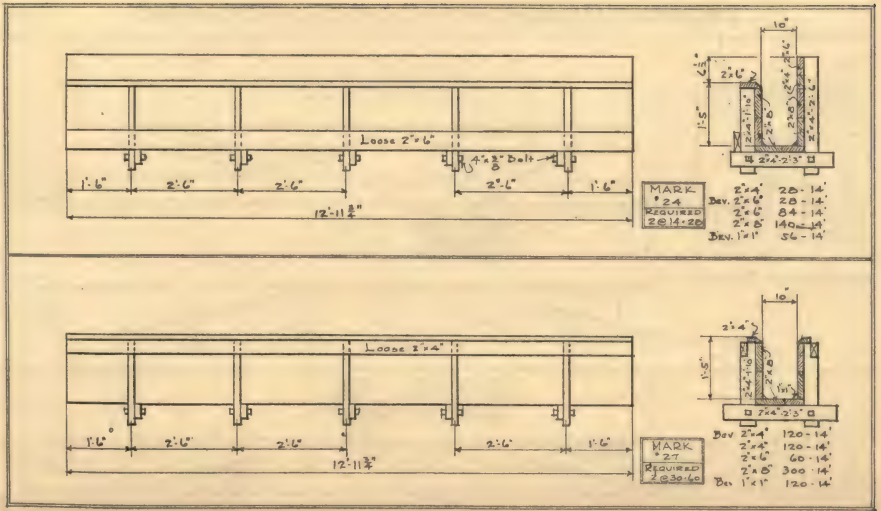
STANDARD TYPES OF BARS.



A TYPICAL FRAMING PLAN.



SHOP DETAILS OF BEAM REINFORCEMENT.



SHOP DETAILS OF BEAM FORMS.

SPECIFICATION FOR REINFORCED CONCRETE.

Architects and engineers in the past have been exceedingly careless in specifying reinforced concrete. Probably this has been because of a lack of knowledge of the subject, but if this is true it is all the more reason why it should be very carefully treated.

The principle points to cover in a specification are the concrete, with the cement, sand and stone or gravel, which go into it, and the reinforcement, covering the steel and the bending and erection of it.

A simple specification is given here which may be varied to suit the reiqurements.

WORK INCLUDED.

The plans indicate the portions of the structure which are to be of reinforced concrete, together with the details of the reinforcement and the thickness of all slabs and sizes of all beams, columns, footings, etc.

The contractor is to provide all materials and labor to fully construct and complete the work, as called for by the plans and in accordance with these specifications.

FORMS.

Forms for the moulding of concrete are to be provided of such a character that after they are removed all slabs will have plane level surfaces and all beams, columns, walls and other portions of the structure will be true to line plumb and

level as required. Surfaces which are to be plastered are to be formed with the rough side of the lumber to the concrete.

The contractor may use such type of forms as he may desire if in the opinion of the engineer the proper results will be obtained, but if it is apparent to the engineer that the concrete will not be properly moulded, the contractor must make such changes as will give satisfactory results.

Forms shall not be removed until the concrete shall have become hard enough to be unquestionably self-supporting. The length of time which the concrete has been in place, shall not be considered as sufficient evidence that the proper set has taken place, but the concrete shall be examined and if in the opinion of the engineer, it is properly set, the forms may be removed.

All forms before placing of the concrete, shall be thoroughly cleaned of all saw dust, blocks, shavings, and dirt or dust of any kind, and the lumber shall be thoroughly wet. Particular attention is called to column forms which must be carefully cleaned out at the bottom, through an opening in the forms provided for the purpose.

CONCRETE.

PROPORTIONS.—Concrete for all portions of the work shall be mixed in the proportions of one part of Portland cement, to two and one-half parts of sand, to four parts of broken stone or gravel, with enough water to make a pasty mixture which will intermingle thoroughly with the reinforcement, but not so wet that the water will drain through the forms, taking with it the cement and sand.

PORTLAND CEMENT.

All cement used shall be of the best grade and shall be approved by the engineer as to brand. Cement shall be delivered at least 12 days before it is to be used and such samples as the engineer may select must satisfactorily pass the following standard tests.

SPECIFIC GRAVITY.

The specific gravity of the cement, thoroughly dried at 100° C., shall be not less than 3.10.

FINENESS.

It shall leave by weight a residue of not more than 8% on the No. 100, and not more than 25% on the No. 200 sieve.

TIME OF SETTING.

It shall develop initial set in not less than thirty minutes, but must develop hard set in not less than one hour, nor more than ten hours.

TENSILE STRENGTH.

The minimum requirements for tensile strength for briquettes one inch square in section shall be within the following limits, and shall show no retrogression in strength within the periods specified.

Age.	*Neat Cement.*	*Strength.*
24 hours in moist air		150-200 lbs.
7 days (1 day in moist air, 6 days in water)		450–550 "
28 days (1 day in moist air, 27 days in water)		550–650 "
	One Part Cement, Three Parts Sand.	
7 days (1 day in moist air, 6 days in water)		150–200 "
28 days (1 day in moist air, 27 days in water)		200–300 "

CONSTANCY OF VOLUME.

Pats of neat cement about three inches in diameter, one-half inch thick at the centre and tapering to a thin edge, shall be kept in moist air for a period of twenty-four hours.

(*a*) A patis then kept in air at normal temperature and observed at intervals for at least 28 days.

(*b*) Another pat is kept in water maintained as near 70° F. as practicable, and observed at intervals for at least 28 days.

(*c*) A third pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely closed vessel for five hours.

These pats, to satisfactorily pass the requirements, shall remain firm and hard and show no signs of distortion, checking, cracking or disintegrating.

SULPHURIC ACID AND MAGNESIA.

The cement shall not contain more than 1.75% of anhydrous sulphuric acid (SO3), nor more than 4% of magnesia (MgO).

Cement not fulfilling the requirements of the 24 hour or 7 day tests shall be held for the 28 day tests. If this fails or if the cement does not come up to the other test required it shall be condemned and immediately removed from the premises.

SAND.

All sand used shall be coarse and perfectly clean being free from clay, loam or other foreign matter.

BROKEN STONE.

Stone shall be broken to a size which will pass through a $\frac{3}{4}''$ ring. A small percentage of

screenings will be permitted, but other foreign matter such as clay if mixed with the broken stone will be sufficient cause for rejection. Sandstone, lime stone, granite, trap rock or other stone approved by the engineer may be used.

GRAVEL.

Gravel shall be of a size not larger than will pass a $\frac{3}{4}''$ ring. Where the proportions here given are used, the gravel shall contain no sand, unless the proportions of sand used are correspondingly reduced. All gravel shall be clean from clay or other foreign matter.

MIXING AND PLACING.

Concrete shall be well mixed in a batch mixer, water being added until the proper consistency is attained. Placing on the forms may be by such means as the contractor sees fit, but it must be done carefully so as not to disarrange the reinforcement. Particular pains is to be taken in the filling of columns, beams and slabs where the reinforcement is of such a type as to interfere with the placing of the concrete.

Columns are to be filled to the bottoms of the beams, being thoroughly churned with a long pole so as to work the concrete into close contact with the reinforcement. After being filled to this height they are to be allowed to set for several hours or more to allow for settlement, after which time the beam and slab forms may be filled. Column forms are to be filled before the reinforcement for beams and slabs is in place.

REINFORCEMENT.

The plans show the type of reinforcement to be used in the various members making up the structure. The contractor's attention is par-

ticularily called to the minute details as no variation will be allowed except by the written consent of the engineer.

STEEL.

All bars used in slabs, beams, columns, footings, etc., shall be of medium steel, having an ultimate strength of not less than 60,000 pounds and an elastic limit of not less than 32,000 pounds per square inch, except the spiral hooping for the columns which shall have an ultimate strength of not less than 100,000 pounds and an elastic limit not less than 80,000 pounds per square inch.

All bars used for longitudinal column reinforcement shall be cut with square ends to exact lengths required. Bars larger than 1½″ in diameter shall have both ends milled for a perfect bearing.

BENDING.

All steel shall be accurately bent to the details shown for the various portions of the structure. Particular care is to be taken in forming the spirals for the columns and in properly fastening them to longitudinal spacing bars so that the pitch of the spiral will be accurately maintained.

ERECTING.

The contractor is to take the greatest care in the erection of reinforcement, keeping a constant eye on it at the point where the concrete is being placed to see that all bars are in their proper locations.

The first reinforcement erected shall be that in the columns, but no reinforcement shall be put into the column forms until the bearing plate at the bottom is properly grouted in place and all sawdust or other rubbish is removed. After

placing the column spirals and properly tieing the longitudinal rods into their proper positions, no more reinforcement is to be erected until the column forms have been filled with concrete.

Beam reinforcement shall be erected next including beam loops, cross bars and spacing bar, and all shall be tied with 14 No. wire so as to be held firmly in place. All anchor bars along walls shall also be erected at the same time as the beam spacing bars.

After the beam reinforcement is completed as above specified, it will form a bearing for the slab rods which are to be carefully located and wired to the spacing bars. Washers are to be threaded over the system of bars lying next to the forms so as to hold them off of the forms, giving a space for the fireproofing of the bars. Reinforcement is to be secured in place by staples driven into the forms, the ends of the staples being clipped off, after the forms are removed, During the placing of the concrete constant attention is to be given to the reinforcement to see that the slab rods are in their proper location *over the beams* and not mashed down below the point called for by the details.

PATCHING AND FINISHING.

After the removal of the forms, any places in the surface of the concrete not properly filled, are to be gone over with cement mortar and finished with a wood or cork float to give a finish as near as possible like the portions not requiring patching.

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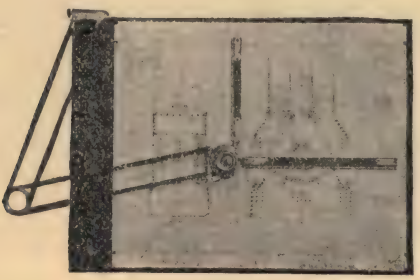

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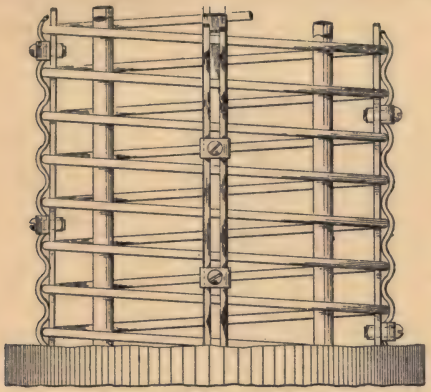

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